US Army Corps
of Engineers

Philadelphia District

DRAFT

DELAWARE RIVER MAIN STEM AND CHANNEL DEEPENING PROJECT

ESSENTIAL FISH HABITAT EVALUATION

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A. INTRODUCTION

In compliance with Section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (1996 amendments), the Philadelphia District, U.S. Army Corps of Engineers, is providing this assessment of the potential effects of construction and maintenance of the Federally authorized Delaware River Main Stem and Channel Deepening Project PA, NJ & DE on essential fish habitats.

The following assessment addresses the physical effects of dredging the existing Delaware River Philadelphia to the Sea navigation channel and construction of the Kelly Island and Broadkill Beach beneficial use projects in Delaware Bay, including a description of the physical habitat, the listed managed species, including specific life stages, and associated major prey species. Based on the potential for adverse effects on designated species Essential Fish Habitat (EFH), recommendations are made for best management practices, which minimize potential adverse effects.

B. PROJECT AUTHORIZATION AND DESCRIPTION

1. Existing Delaware River Philadelphia to the Sea Federal Navigation Project

The existing Delaware River, Philadelphia to the Sea, Federal navigation project was adopted in 1910 and modified in 1930, ’35, ’38, ’45, ’54 and ’58. The existing project provides for a channel from deep water in Delaware Bay to a point in the bay, near Ship John Light, 40 feet deep and 1,000 feet wide; thence to the Philadelphia Naval Base, 40 feet deep and 800 feet wide, with a l,200-foot width at Bulkhead Bar and a 1,000-foot width at other channel bends; thence to Allegheny Avenue Philadelphia, PA; 40 feet deep and 500 feet wide through Horseshoe Bend and 40 feet deep and 400 feet wide through Philadelphia Harbor along the west side of the channel. The east side of the channel in Philadelphia Harbor has a depth of 37 feet and a width of 600 feet. All depths refer to mean low water. The 40-foot channel from the former Naval Base to the sea was completed in 1942. The channel from the former Naval Base to Allegheny Avenue was completed in 1962.

There are 19 anchorages on the Delaware River. The Mantua Creek, Marcus Hook, Deepwater Point, Reedy Point, Gloucester and Port Richmond anchorages are authorized under the Philadelphia to the sea project. The remaining 13 are natural, deep-water anchorages. The authorized anchorage dimensions are as follows:
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Mantua Creek:	40’ X 2,300’ X 11,500’ (mean)
Marcus Hook:	40’ X 2,300’ X 13,650’ (mean)
Deepwater Point:	40’ X 2,300’ X 5,200’ (mean)
Reedy Point:	40’ X 2,300’ X 8,000’ (mean)
Port Richmond:	37’ X 500’ (mean) X 6,400’
Gloucester:	30’ X 400’ (mean) X 3,500’

Mantua Creek anchorage is currently maintained to about 60% of the authorized width and a 37-foot depth. The Marcus Hook anchorage, enlarged in 1964, is maintained to authorized dimensions. The anchorage at Port Richmond is about 35 feet deep, as are the Reedy Point and Deepwater Point anchorages. The Gloucester anchorage requires no dredging and is currently deeper than authorized.

There are wide variations in the amount of dredging required to maintain the Philadelphia to the sea project. Some ranges are nearly self maintaining and others experience rapid shoaling. The 40-foot channel requires annual maintenance dredging in the amount of 3,455,000 cubic yards. Of this amount, the majority of material is removed from the Marcus Hook (44%), Deepwater Point (18%) and New Castle (23%) ranges. The remaining 15 percent of material is spread throughout the other 37 channel ranges. The historic annual maintenance quantities for the Marcus Hook and Mantua Creek anchorages are 487,000 and 157,000 cubic yards, respectively.

The Federal government has the responsibility for providing the necessary dredged material disposal areas for placement of material dredged for project maintenance. There are currently seven upland sites and one open-water site, located in Delaware Bay, that are used for this purpose. The seven confined upland sites are National Park, Oldmans, Pedricktown North, Pedricktown South, Penns Neck, Killcohook and Artificial Island. The open water site in Delaware Bay is located in the vicinity of Buoy 10. This site is only approved for placement of sand.

2. Authorized Delaware River Main Stem and Channel Deepening Project, Pennsylvania, New Jersey, and Delaware

The Delaware River Main Stem and Channel Deepening Project, Pennsylvania, New Jersey, and Delaware, was authorized by Public Law 102-580, Section 101(6) of the Water Resources Development Act of 1992. The Philadelphia Port Authority is the non-Federal sponsor for this project.

The authorized deepening project as shown on Figure 1 provides for modifying the existing Delaware River Federal Navigation channel (Philadelphia to Sea Project) from 40 to 45 feet at Mean Low Water) with an allowable dredging overdepth of one foot, following the existing channel alignment from Delaware Bay to Philadelphia Harbor, Pennsylvania and Beckett Street Terminal, Camden, New Jersey. The channel side slopes are 3 horizontal to 1 vertical. Bottom channel widths will be the same as the existing channel, but with side slopes, the top of the channel will be a maximum of 15 feet wider on each side of the channel (5 feet vertical x 3 horizontal = 15 feet). The project also includes deepening of an existing Federal access channel at a 45-foot depth to Beckett Street Terminal, Camden, New Jersey. No wetlands will be filled as a result of this project.

The existing channel is maintained at a depth of 40 feet deep at mean low water. Only portions of the channel that are currently between 40 feet and 45 feet at mean low water will be dredged for the deepening project. The surface area of the Delaware estuary from the Ben Franklin Bridge to the capes (excluding tidal tributaries) is approximately 700 square miles. The Philadelphia to the sea Federal navigation channel has a surface area of 15.3 square miles, or approximately 2.2 percent of the total estuary surface area. For the 45-foot deepening project, 8.5 square miles would be dredged; this is 1.2 percent of the total estuary surface area and 55 percent of the existing channel. The remaining 6.8 square miles of the existing channel is already 45 feet deep or deeper.

The channel width (same as the existing 40-foot project) is 400 feet in Philadelphia Harbor (length of 2.5 miles); 800 feet from the Philadelphia Navy Yard to Bombay Hook (length of 55.7 miles); and 1,000 feet from Bombay Hook to the mouth of Delaware Bay (length of 44.3 miles).

Figure 1. Delaware River Main Channel Deepening Project.

The project includes 11 bend widenings at various ranges as listed below as well as provision of a two space anchorage to a depth of 45 feet at Marcus Hook, Pennsylvania. The existing turning basin adjacent to the former Philadelphia Naval Shipyard will not be deepened as part of the 45-foot project.

Note that the Miah Maull – Cross Ledge bend is no longer being widened. Also, included as part of the Federal project is the relocation and addition of buoys at the 11modified channel bends. Ten new buoys are proposed: Philadelphia Harbor (2), Tinicum Range (1), Eddystone Range (1), Bellevue Range (3), Cherry Island Range (1), Bulkhead Bar Range (1), and Liston Range (1). Additional information regarding buoy modification can be found at : http://www.nap.usace.mil/cenap-pl/buoymod.pdf

The following channel bends will be modified:

1. LISTON-BAKER: Maximum width increase on the east edge of 250 feet, over a distance of 4,500 feet south of the apex, and extending 3,900 feet north from the apex (BW2 - channel station 275 + 057);

2. BAKER-REEDY ISLAND: 100-foot width increase at the west edge apex of the bend over a distance of 3500 feet both north of and south of the apex (BW3 - channel station 265 + 035);

3. REEDY ISLAND-NEW CASTLE: Maximum widening of 400 feet at the west apex of the bend, tapering to zero over a distance of 3,200 feet south of the apex and to zero over a distance of 4,000 feet north of the apex (BW4 - channel station 238 + 982);

4. NEW CASTLE-BULKHEAD BAR AND BULKHEAD BAR-DEEPWATER: The west edge of Bulkhead Bar range is extended by 300 feet to the south and 300 feet to the north; the widening tapers to zero at a distance of approximately 3,000 feet south of the south end of Bulkhead Bar and 3,000 feet north of the north end of Bulkhead bar (BW5 - channel station 212 + 592 and 209 + 201);

5. DEEPWATER-CHERRY ISLAND: A maximum channel widening of 375 feet is required at the western apex of the bend. The widening tapers to zero at a distance of about 2,000 feet both north and south of the apex (BW6 - channel station 186 + 331);

6. BELLEVUE-MARCUS HOOK: The east apex of the bend requires a 150 foot widening over existing conditions, along a total length of approximately 4,000 feet (BW7 - channel station 141 + 459);

7. CHESTER-EDDYSTONE: The southwest apex of the bend requires a maximum 225 foot widening, with a transition to zero at the northeast end of Eddystone range, over a linear distance of approximately 6,000 feet (BW8 - channel station 104 + 545);

8. EDDYSTONE-TINICUM: The northeast apex of this bend requires a 200 foot widening, with a transition to zero at a distance of about 1,200 feet northeast and southwest of the bend apex (BW9 - channel station 97 + 983);

9. TINICUM-BILLINGSPORT: The north channel edge of Billingsport was widened by 200 feet. At the northern apex of the Tinicum-Billingsport bend, this results in a maximum widening of approximately 400 feet, with a transition to zero at a distance of about 2,000 feet west of the apex (BW10 - channel station 79 + 567);

10. BILLINGSPORT-MIFFLIN: The south apex of the bend was widened a maximum of 200 feet to the south, and transitioned to zero at a distance of approximately 3,000 feet northeast of the apex (BW11 - channel station 72 + 574);

11. EAGLE POINT-HORSESHOE BEND: The northwest edge of Horseshoe Bend requires a maximum widening of 490 feet to the north. The widening transitions to zero at a distance of approximately 4,000 lineal feet west of the west end of Horseshoe Bend, and at a distance of 1,500 lineal feet north of the north end of the bend (BW12 - channel station 44 + 820 to 41 + 217).

Table 1 Bend Modification Summary (mean elevations represent existing depths)

Bend Modifications	Area (Acres)	Substrate	Mean Elevation (Feet)
Listen - Baker	31.0	Silt	43.3
Baker – Reedy Island	2.8	Sand	41.4
Reedy Island – New Castle	21.7	Silt	42.8
New Castle – Bulkhead Bar and Bulkhead Bar - Deepwater	7.7	Sand	41.2
Deepwater – Cherry Island	12.1	Silt	42.6
Bellevue – Marcus Hook	11.4	Silt	43.5
Chester - Eddystone	12.3	Silt	41.1
Eddystone - Tinicum	11.3	Sand	42.1
Tinicum - Billingsport	55.4	Silt	39.6
Billingsport – Mifflin	7.7	Sandy-Silt	43.0
Eagle Point – Horseshoe Bend	42.5	Sandy-Silt	38.3
Total Area	**215.9**		

Construction and maintenance of the 45-foot project for a 50-year period will only utilize existing, Federally owned confined disposal facilities. The current dredged material disposal plan for the riverine portion of the project will only utilize the existing Federal sites (National Park, Oldmans, Pedricktown North, Pedricktown South, Penns Neck, Killcohook, Reedy Point North, Reedy Point South, and Artificial Island). In Delaware Bay, material will be used for beneficial use projects at Kelly Island and Broadkill Beach. Since completion of the Supplemental Environmental Impact Statement in 1997, further engineering studies have reduced the quantities of material to be dredged (initial and maintenance) thereby reducing the amount of disposal capacity needed. Due to the decrease in overall project quantities, the previously proposed beneficial use project at Egg Island Point will be deferred.

For the initial deepening, material would be dredged and placed by hydraulic cutterhead and hopper dredges in confined upland disposal facilities in the Delaware River portion of the project area and for beneficial uses in Delaware Bay (Figure 1). In addition, 77,000 cubic yards of rock would be removed in the vicinity of Marcus Hook, Pennsylvania and placed in the Fort Mifflin confined disposal facility in Philadelphia. The initial dredging quantities and placement locations are distributed among the project reaches as follows:

Reach AA	994,000 cubic yards	National Park
Reach A	1,666,600 cubic yards	Pedricktown North
Reach B	4,664,900 cubic yards	Pedricktown North and South, Oldmans
Reach C	2,502,800 cubic yards	Killcohook, Reedy Point South
Reach D	2,051,100 cubic yards	Reedy Point South, Artificial Island
Reach E	4,081,700 cubic yards	Kelly Island, Broadkill Beach
Total	approximately 16,000,000 cubic yards	

Dredging equipment is described in Sections 3.1.2.3 and 10.4.2.1 of the 1997 Supplemental Environmental Impact Statement. The channel dredging project will use hydraulic hopper and cutterhead dredges. See Section 3.0 of the 1997 SEIS. Rock will be blasted and removed from the channel with a bucket dredge. See Figure 5 for the type of dredge to be used in the various project reaches and the scheduled months for construction.

The definition of project Reaches AA through E is as follows:

Reach AA/A extends from the upper project limit at Allegheny Avenue, Philadelphia PA to Billingsport Range, located near the Philadelphia International Airport. Reach B extends from Tinicum Range, located opposite of the airport to Cherry Island Range, located opposite of Wilmington, DE. Reach C extends from Deepwater Point Range, located below Wilmington, DE to New Castle Range, located at the mouth of the Chesapeake and Delaware Canal. Reach D extends from Reedy Island Range, located south of the Chesapeake and Delaware Canal to Liston Range, located just north of Delaware Bay. Reach E covers the remaining portion of the project area from the lower portion of Liston Range in the upper portion of Delaware Bay to naturally deep water in the lower portion of the bay.

Approximately 77,000 cubic yards of bedrock from the Delaware River near Marcus Hook, PA (River Mile 76.4 to River Mile 84.6) would be removed to deepen the navigation channel to a depth of 47 ft below mean lower low water. In order to remove the rock by blasting, holes drilled into the rock are packed with explosive and inert stemming material at the surface in order to direct the force of the blast into the rock. The depth and placement of the holes along with the size and blast timing delays of the charges control the amount of rock that is broken and energy levels released during the blasting operations. The project would be conducted by repeatedly drilling, blasting, and excavating relatively small areas until the required cross section of bedrock is removed.

Blasting is scheduled to occur in December and January over a two year period. The following measures will be employed to protect fish during the blasting period:

The pre- and post-blast monitoring for fish including the shortnose sturgeon shall be conducted under the supervision of a principal biologist that has at least a Master of Science degree in fisheries biology or similar fields approved by the Contracting Officer. In addition, the principal biologist must have at least 3 years of experience in the estuarine/marine environment, which includes working with shortnose sturgeon, and the principal biologist must have obtained in their name the appropriate ESA permits to work with shortnose sturgeon.

Before each blast, four sinking gillnets (5.5 inch stretched mesh. 328 feet [I00 meters] long, 9.8-13.1 feet [3-4 meters] high) will be set to surround each blast area as near as feasible. These nets shall be in place for at least 3 hours and none of the nets will be removed any sooner than 1 hour before the blast. This may require ovenight sets. The nets shall be manned continuously to prevent obstructing the channel to ship traffic. Any sturgeon removed (shortnose or Atlantic) shall be tagged and released at a location approved by the NMFS.

Within 10 minutes of blast, channel nets (1-2 inch mesh) will be set during daylight hours downcurrent of the blast area and within approximately 300 feet from the blast area in order to capture and document dead or injured fish. The channel net shall have a minimum head rope length of 100 feet and should be retrieved approximately one hour later.

Surveillance for schools of fish will be conducted by vessels with sonar fish finders (with a LCD display screen) for a period of 20 minutes before each blast. The surveillance zone will be approximately circular with a radius of about 500 feet extending outward from each blast set. If fish schools are detected, blasting will be delayed until they leave.

Two scare charges shall be used at each blast. The scare charges shall be detonated in close proximity to each blast. Each individual scare charge shall not exceed a TNT-equivalent weight of 0.1 lb. The detonation of the first scare charge will be at 45 seconds prior to the blast, with the second scare charge detonated 30 seconds prior to the blast. It is necessary to employ the scare charges and conduct the surveillance surveys before each blast, as some fish have been found to recolonize the blast zone soon after a detonation.

All blast holes will be stemmed to suppress the upward escape of blast pressure from the hole. The minimum stemming shall be 2 feet thick. Stemming shall be placed in the blast hole in a zone encompassed by competent rock. Measures shall be taken to prevent bridging of explosive materials and stemming within the hole. Stemming shall be clean, angular to subangular, hard stone chips without fines having an approximate diameter of 1/2-inch to 3/8-inch. A barrier shall be placed between the stemming and explosive product, if necessary, to prevent the stemming from setting into the explosive product.

Blast pressures will be monitored and upper limits will be imposed on each series of 5 blasts. Average peak pressure shall not exceed 70 pounds per square inch (psi) at a distance of 140 feet.

Maximum peak pressure shall not exceed 120 psi at a distance of 140 feet.

Pressure will be monitored for each blast only at a distance of 140 feet.

The Philadelphia District is currently processing a contract with a geotechnical consultant to conduct a detailed geophysical investigation of the rock-cut areas in the near future. The purpose of this investigation is to perform a specialized type of resistivity survey on the channel floor to obtain additional detailed information on the location, quality and condition of the bedrock materials that underlie the existing channel bottom. This study is being conducted in anticipation that we will acquire additional detailed information on the quantity and integrity of the existing bedrock that has to be removed, and based on review of previous rock core boring performed in the rock-cut areas, will enable us to more accurately focus and limit the amount of rock blasting required.

2.1 Kelly Island, Delaware Wetland Restoration

The Kelly Island wetland restoration has been refined since the publication of the SEIS (July, 1997) based on coordination with DNREC, NMFS and the US Fish and Wildlife Service. An updated description appears below.

The Kelly Island Project is a wetland restoration. The main purposes of the project are to restore intertidal wetlands using dredged sediment from the deepening of the Delaware River navigation channel, stem erosion of the Kelly Island shoreline estimated at 20 feet per year, provide extensive sandy beach for spawning horseshoe crabs, and provide continued protection to the entrance of the Mahon River.

Restoring wetlands in this environmentally sensitive area has been a high priority for the State of Delaware. A plan has been developed with the assistance of the Federal and State resource agencies to restore 60 acres of intertidal habitat (Figures 2 and 3). In addition to wetlands, approximately 60 acres of beach will be created. A total of 120 acres of aquatic habitat (below mean high water) will be filled. The site will be constructed as an impoundment and remain as such until the sediments consolidate and vegetation becomes established. Areas of the site that don't vegetate naturally will be planted. After the site has settled, the State of Delaware will decide whether to open the site up to unregulated tidal inundation. The option to convert back to an impoundment will be maintained. The site has been designed for the restoration of intertidal wetlands. Following construction, the site will be monitored to insure that the goals of the project are met and that no adverse impacts occur, particularly impacts to oyster beds. Issues identified as a result of monitoring will be corrected through a program of adaptive management.

Features of the project include:

- Sixty acres of wetlands where the substrate will consist of an estimated 55,000 cubic yards of silt and 645,000 cubic yards of sand.
- An offshore containment dike made of 1.7 million cubic yards of sand that will provide up to 5,000 linear feet of sandy beach. The crest of the dike will be at +10 ft MLW providing substantial spawning habitat for horseshoe crabs.
- A geotextile tube within the core of the offshore dike that provides overwash protection and contingency protection against breaching.

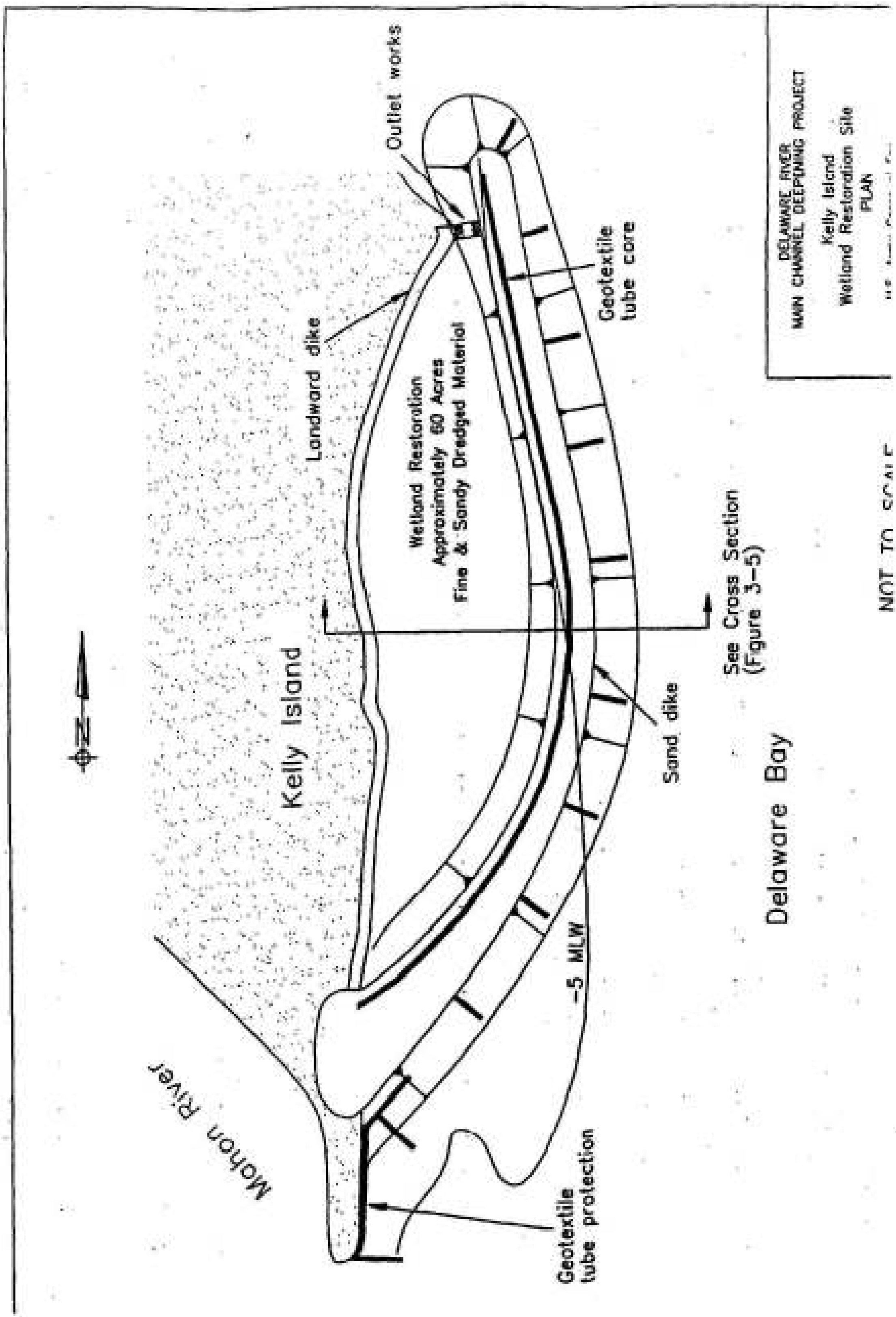


Figure 2. Kelly Island Plan.

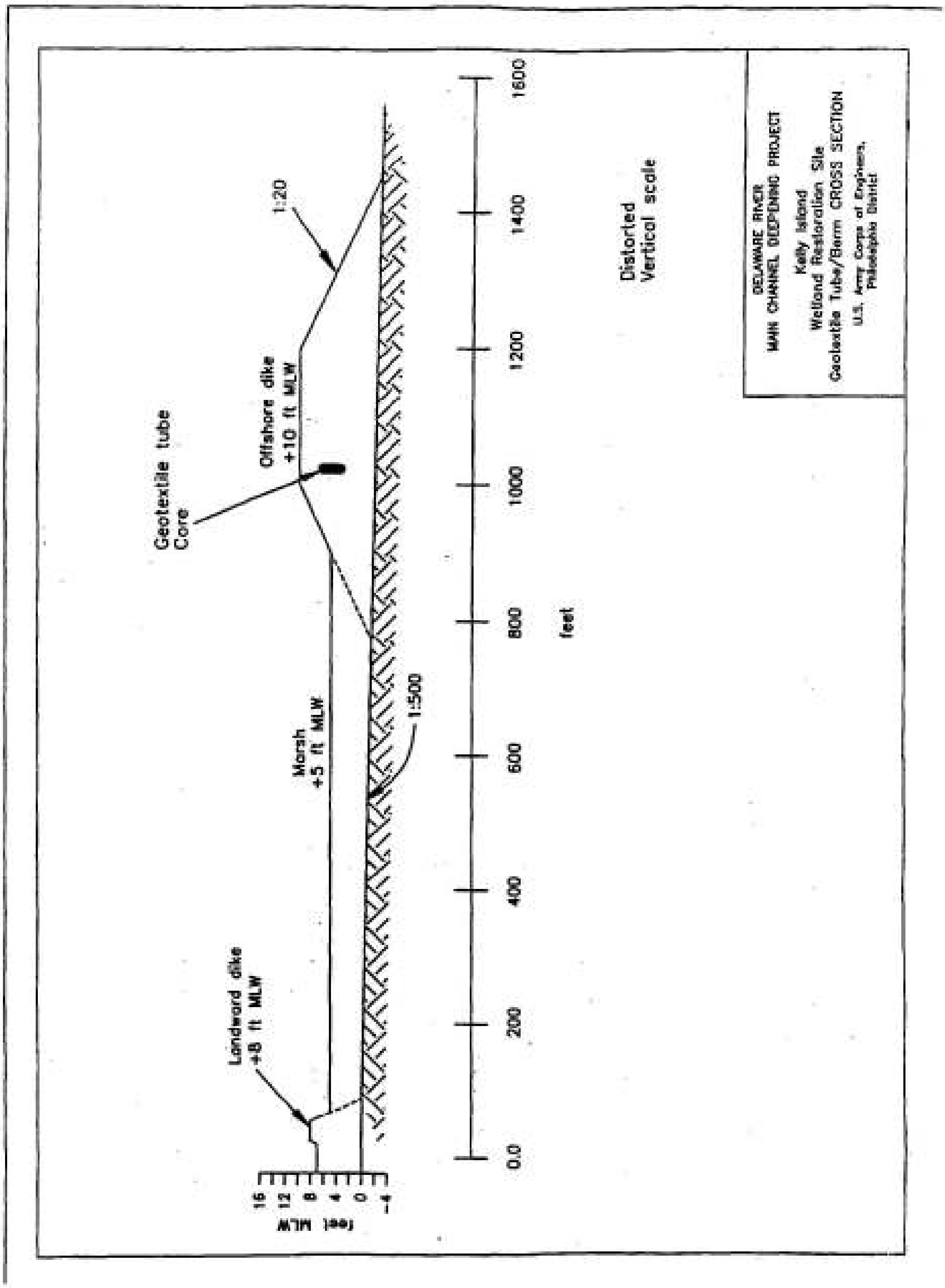


Figure 3. Kelly Island Geotextile Tube/Berm Cross Section.

- Timber groins to limit sand transport along the beach.
- Options for water level control or free tidal exchange with the bay.

Construction of the sand dikes will begin at the south end gaining access to the site from the Mahon River channel. Once the dikes are constructed, the interior will be filled. Filling will take approximately five months. The total time to construct Kelly Island is six months. Construction is scheduled to occur between April and September to preclude potential dredging impacts to overwintering blue crabs between December and March. Once the containment area/beach is constructed, fine-grained sediment will be placed first followed by placement of sand. The volume of sediment to be placed in the site will ultimately achieve a surface elevation of +5 feet MLW which is at the upper part of the tidal range. After construction, and possibly for several years, the water levels in the site will be controlled.

The offshore dike will have a crest elevation of +10 feet MLW. This elevation is coincident with the water level for a return interval between 10 and 25 years. It is only during rare events that this sand dike will be overtopped. The dike is expected to provide up to 5,000 linear feet of spawning habitat for horseshoe crabs.

The crest width of the dike will be 200 feet at its narrowest and 350 feet at its widest. The volume of sand in the cross section of the dike will be constant, i.e. 845 cubic yards per linear yard. Therefore, the crest width of the dike in shallow water will be greater than in deeper water. The total volume of sand required for the offshore dike is 1.7 million cubic yards (which includes a quantity sufficient to offset an estimated one foot of settlement). The offshore slope of the dike is estimated to be initially 1:20, and after the first year of “weathering” it should equilibrate to a milder 1:40 slope.

The southern end of the offshore dike will terminate on the island. The elevation of the crest of the dike will transition from +10 feet MLW to the +7 feet MLW (approximate) elevation of the existing marsh. The dike will extend onto the island far enough to prevent southerly waves at high water levels from damaging any portion of the interior of the project. The dike will also extend beyond its connection with the landward dike.

The northern end of the offshore dike will extend approximately 300 feet beyond Deepwater Point roughly parallel to the shoreline. The outlet works for the project will be placed at Deepwater Point, and so the offshore dike will protect that location.

A geotextile tube will be placed within the offshore dike as a factor of safety against a breach in the dike due to an extreme event and overwash. The crest of the tube will be placed to a crest elevation of +7 feet MLW. The tube will then be buried under an additional three feet of sand bringing the crest of the dike up to elevation +10 feet MLW. The protection that the tube provides should allow time for maintenance or repair work to be planned and executed if a breach should develop due to overwash.

The geotextile tube at Kelly island will be buried, therefore its lifespan is indefinite. It would only be exposed as a result of a storm event, and is intended to protect the marsh in the event of a massive storm that erodes the beach. If the tube becomes exposed and there is a rupture, it can be patched in the field. After the first or second season the beach and marsh will behave as any other natural shoreline, except that the groins will prolong the life of this mile of shore.

A landward dike will be constructed along the edge of the existing marsh with a crest elevation of +8 feet MLW. The dike crest width will be 20-30 feet. The dike will prevent dredged material from flowing across or settling in the existing marsh. The dike will be built-up by trucking sand from the larger offshore dike to the landward dike during construction. The dike will not be constructed by hydraulic placement of sand. The dike will be left in place after construction to impound the site. In the future, if the State of Delaware decides that the site should function with unregulated tidal exchange with the bay, the landward dike may be removed. However, if the capability to impound the site at some future date is necessary, then the landward dike should not be removed.

Groins made of either timber or vinyl will be placed along the perimeter of the offshore dike to help limit longshore transport. Although the cross-section of the dike is designed to sustain sediment losses for many years without losing any of its function, groins will increase the longevity of the project, reduce potential maintenance, and add a factor of safety against the risk that sand will be transported south along the project into the Mahon River entrance. The groins will extend seaward from the crest of the dike about 240 feet. They will extend landward from the crest of the dike about 50 feet. Therefore, their total length is 290 feet. The groins will follow the initial profile of the dike having a 1:20 slope from the crest of the berm to MLW. The crests of the groins will be nominally about 2 feet above the sand berm initial cross-section. The groins will be spaced about 750 feet apart. At both ends of the project, terminal timber sheet-pile groins will be constructed that are 450 feet long. The groins will be constructed after the sand berm is constructed.

The outlet works for the marsh will be placed through a cross-shore sand dike at the north end of the project extending from the tip of Deepwater Point to the offshore dike. The elevation of the crest of the cross-shore dike will be +8 feet MLW which is sufficient to prevent even the annual highest high-tide from overtopping the dike. This elevation also provides sufficient freeboard so that water levels in the site can be held high if needed. The cross-shore dike does not need additional elevation to prevent wave overtopping because it is protected from waves by the offshore dike. A geotextile tube like the one described for the offshore sand dike will be placed in the core of the cross-shore dike. The flows through the outlet works during dredging depend mainly on the depth of water above the weir crests.

The outlet works will have outflow pipes that pass through the core of the cross-shore dike. The cross-section of the cross-shore dike will be held to a minimum to minimize the length of outlet pipe required. The actual crest width of the dike will depend on the stability of the foundation upon which the dike is built. The dike will be filled until a stable cross-section is achieved. The dike will be constructed by moving sand from the offshore dike with heavy equipment so that steeper side slopes can be achieved which will minimize the dike cross-section.

The outlet works provided at the north end of the project will control release of water during dredging. Several drop inlets are planned. The capacity of the outlet works will depend on the size of the dredge pump and discharge line, the frequency of hopper discharges (cycle time), and water control requirements for post-construction marsh management. But the potential to release water at a rate as high as 75-100 cfs may be required.

An outlet works at the southern end of the project will not be necessary for dredging purposes. However, tidal connection to the southern end of the site may be desired after the marsh develops and natural flow patterns emerge. Any additional tidal connection will be achieved, for example, through small tidal guts through the existing marsh to the Mahon River and not through the offshore dike. A tidal gut presently exists near the south end of the project and may provide an ideal connection with the Mahon River.

Further description and need for the Kelly Island wetland restoration can be found in Section 3.3.3.2 of the SEIS (July, 1997).

2.2 Broadkill Beach, Delaware Beach Nourishment

The Federally authorized plan for coastal and storm damage reduction along the community of Broadkill Beach is shown in Figure 4. The Delaware Bay Coastline, DE & NJ – Broadkill Beach, DE project was authorized for construction by Title I, Section 101 (a) (11) of

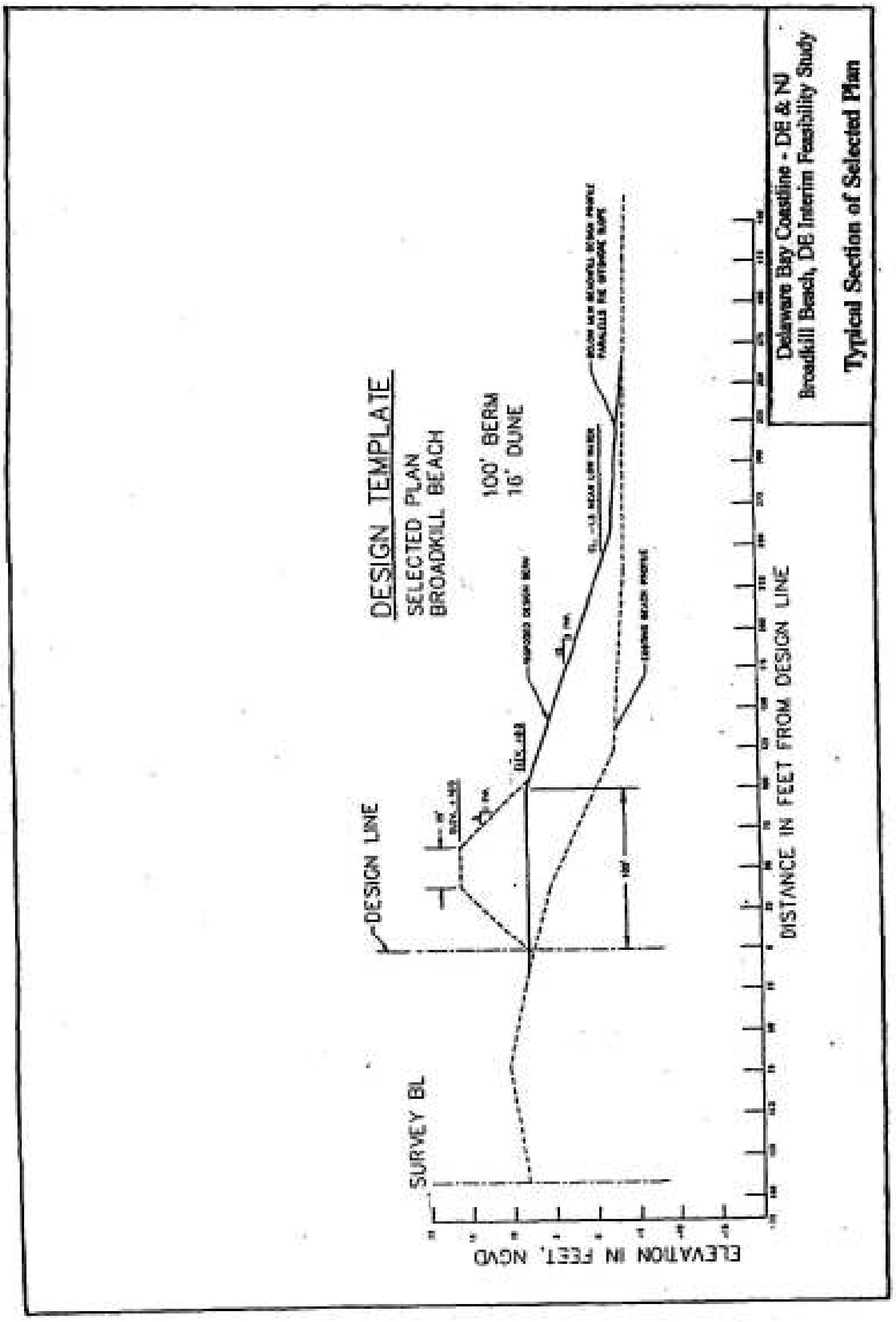


Figure 4. Broadkill Beach Design Template.

the Water Resources Development Act of 1999. Broadkill Beach was the subject of the Delaware Bay Coastline – Delaware and New Jersey, Broadkill Beach, Delaware Interim Feasibility Study. A final Feasibility Report and Environmental Impact Statement is dated September 1996. The Delaware Department of Natural Resources and Environmental Control is the non-Federal project sponsor. The project area is located along the Delaware Bay Coastline at Broadkill Beach, Sussex County, Delaware. A total of 35 acres of aquatic habitat (below mean high water) will be filled. The authorized plan for this project has the following components:

* A berm extending seaward 100 feet from the design line at an elevation of +8 feet NGVD. The beachfill extends from Alaska Avenue southward for 13,100 linear feet. Tapers of 1,000 feet extending from the northern project limit and 500 feet extending from the southern project limit brings the total project length to 14,600 linear feet.

* On top of the berm lies a dune with a top elevation of +16 ft NGVD and a top width of 25 feet.

* A total initial volume of 1,598,700 cubic yards of sand fill would be placed along the area. This fill volume includes initial design fill requirements and advanced nourishment.

* Periodic nourishment of 358,400 cubic yards of sand fill would be placed every 5 years.

* Planting of 174,800 square yards of dune grass and 21,800 linear feet of sand fence are included for dune stability.

* Vehicular access to the beach would be provided at Route 16 in the center of Broadkill Beach. Sand fence would be used to create a path 12 feet wide along both sides of the dune at a skewed angle to the dune alignment. This would allow vehicles to climb along the side of the dune at a flatter slope than 5H:1V.

• Pedestrian access paths would be located at each street end in a similar fashion as the vehicular access. However, the access paths would be smaller in width and at a somewhat steeper slope.

For protection of the sandbar shark, the following measures will be implemented to allow construction between 1 May and 15 September:

A sand dike, 200 to 300 feet in length, will be constructed above mean high water (MHW) to contain dredged material that is pumped landward of it. The dike will be constructed using existing sand on the beach. The dike will be long enough that most dredged material will drop out on the beach and not return to the bay. As material is deposited the dike may be repositioned seaward to contain the required tilling above MHW for that section of Beach. The slurry will still be controlled by the dike along the shoreline. No dredged material will be hydraulically placed below MHW during the restricted period. The dike will be extended down the beach as the area behind the dike is tilled and the dredged pipe is lengthened. The dredged material that has been deposited will be built into dunes. It is expected that little of this material will be re-deposited by wave action during the spring/summer window period since weather is generally mild, except for possible hurricanes. After September 15, some dredged material will be graded into the bay to widen the beach.

The dredge pipe will be placed on pontoons for a minimum of 1000 feet, beginning at approximately elevation -4.7 NGVD, extending offshore to avoid disrupting along shore traveling by the young sandbar sharks. This distance will be determined by the National Marine Fisheries Service. The remainder of the pipeline extending to the beach, and back to the dredge, can rest on the bottom.

Sand will be dredged from the channel and pumped on the beach between April and June. The sand will be graded by bulldozer to achieve the construction template between October and March.

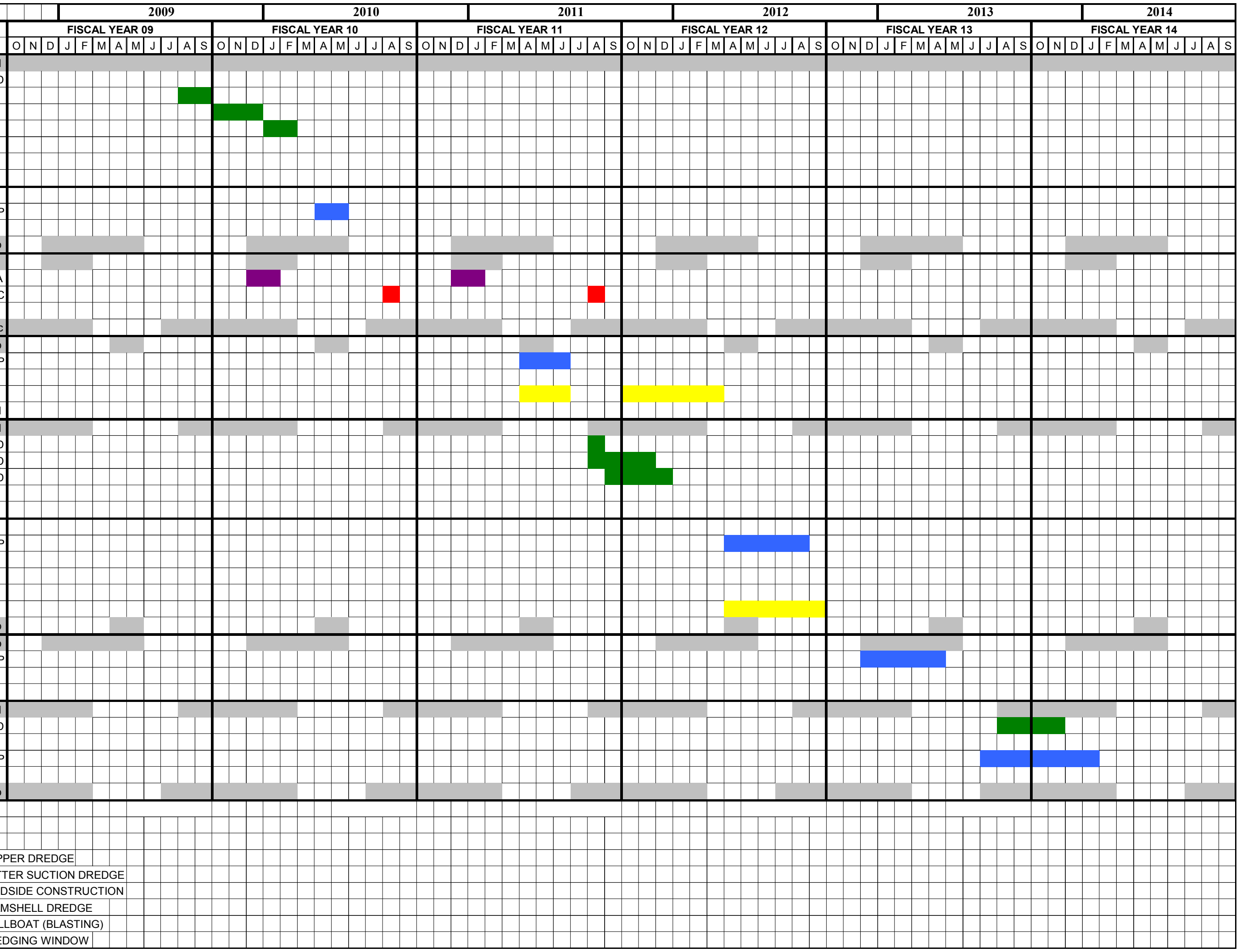
2.3 Construction Schedule

Figure 5 shows the construction schedule and the type of dredge that would be used for different sections of the river for the Deepening Project. Dredging was scheduled to be in compliance with Delaware River Basin Fish and Wildlife Management Cooperative recommended dredging restrictions for protection of fishery resources in the Delaware River and Bay. Time periods shaded grey are the recommended periods for hopper dredging, cutterhead pipeline dredging, bucket dredging, sand placement and blasting. All windows will be met in Reaches AA, A, B, C, D, and E above River Mile 32. Dredging below River Mile 32 and shoreline work at Kelly Island and Broadkill Beach can not meet the recommended windows. The only period of time that meets all recommended restrictions for these areas is the first half of the month of April. The construction periods for Kelly Island and Broadkill Beach are presented above.

2.4 Operation and Maintenance

The required maintenance dredging of the 45-foot channel will increase by 862,000 cubic yards per year (cy/yr) from the current 3,455,000 average cy/yr for the 40-foot channel for a total of 4,317,000 cy/yr. It is expected that maintenance areas for the 40-foot channel will remain the same for the 45-foot project, however it is anticipated that an approximate 10 percent increase will occur in the quantity of material dredged. Maintenance dredging for the riverine portion of the channel is done with a hydraulic cutterhead dredge with material placed in existing upland confined disposal facilities. This work typically takes about two months and is done between the months of August and December. Maintenance dredging in Delaware Bay is typically accomplished with the Corps' MacFarland hopper dredge. This material is placed in the existing overboard placement site known as the Buoy 10 site. Work is scheduled based on the availability of the MacFarland.

River Mile	Duration (Mo)	Estimated Quantity (cy)	Dredge	
				hyd
				HYD
68.3	1.65	932,600	1	
63.9	2.76	597,800	1	
60.3	1.38	972,400	1	
		2,502,800		
	1.13	**396,300**	1	HOP
55.8				
				hop
				bla
	3.17		1	BLA
	1.27		1	MEC
		77,000		
				mec
				hop
	3	**1,598,700**	2	HOP
15.6				
				hyd
				hyd
	0.89	1,671,400	1	HYD
	3.51	1,050,700	1	HYD
	3.13	1,942,800	1	HYD
85.9				
		4,664,900		
	4.5		2	HOP
36.4		345,800		
32.1		55,500		
30.8		2,081,700		
		2,483,000		hop
				hop
51.8	4.63	**1,654,800**	1	HOP
				hyd
	2.88	994,000	1	HYD
99.2				
	6.1	1,666,600	1	HOP
96.8				
		2,660,600		hop
	40	15,961,100		



HOP HOPPER DREDGE
HYD CUTTER SUCTION DREDGE
LANDSIDE CONSTRUCTION
MEC CLAMSHELL DREDGE
BLA DRILLBOAT (BLASTING)
DREDGING WINDOW

Figure 5. Delaware River Main Channel Deepening Project Construction Schedule

C. DESCRIPTION OF THE STUDY AREA

The project area encompasses the Delaware River estuary from Philadelphia, Pennsylvania to the mouth of Delaware Bay. The area extends over 100 river miles, and borders 10 counties in the Commonwealth of Pennsylvania, and the States of New Jersey and Delaware. The upstream portion of the project area includes the cities of Philadelphia, Pennsylvania and Camden, New Jersey, which together form the fifth largest metropolitan area in the United States. In conjunction with the port of Wilmington, Delaware, this area supports the largest freshwater port in the world. The area maintains a high concentration of heavy industry, including the nation's second largest complex of oil refineries and petrochemical plants. Below Wilmington, Delaware, the river broadens into the Delaware Bay. Although many small towns are located along the bay's margins, the surrounding drainage basin is predominantly rural. The bay supports both-commercial and sport fisheries along with other recreational activities, is broad and shallow, and is surrounded by extensive salt marshes and agricultural land.

Kelly Island is located on the western shore of Delaware Bay in Kent County, Delaware. It is bounded by Delaware Bay to the east, Simons River to the north, and Mahon River to the south and west. The Mahon River is an important port for local commercial and recreational fishermen. The reconstruction project would principally affect the lower eastern shore of the island, facing the Delaware Bay. Shoreline erosion is occurring at an estimated rate of 20 feet per year, mostly from the loss of salt marsh. Depths in Delaware Bay waters adjacent to Kelly Island are shallow and average approximately 9 feet out to the main channel, 5 miles to the east. The beach and access road to the south of the entrance of Port Mahon is severely eroded. Construction to stabilize the shoreline has occurred in the past as evidenced by the rock, sheet bulkheads, and construction rubble placed along the shoreline. The road leading to the State of Delaware dock and ramp facilities is frequently washed out by storm events, and over time, the road has been moved farther back into the salt marsh.

Broadkill Beach is located close to the mouth of Delaware Bay. The beach is a continuous band consisting almost entirely of clean sand and small (<2 cm) gravel. The beach is currently protected by a series of groins that extend from high on the beach, out into the water at right angles to the shoreline. Shoreward, the beach is backed by varying widths of sparsely vegetated dunes, and a dense residential area. Broadkill Beach was the subject of the Delaware Bay Coastline – Delaware and New Jersey, Broadkill Beach, Delaware Interim Feasibility Study. A final Feasibility Report and Environmental Impact Statement is dated September 1996.

D. ANALYSIS OF EFFECTS ON EFH

Effects on Physical Habitat

The following activities will be conducted within designated EFH to construct the Delaware River Main Channel Deepening Project: (1) dredging the navigation channel; (2) wetland restoration at Kelly Island, Delaware; (3) beach nourishment at Broadkill Beach; and (4) rock blasting near Marcus Hook, Pennsylvania. There are a number of Federally managed fish species where essential fish habitat (EFH) was identified for one or more life stages within the project impact areas. Fish occupation of waters within the project impact areas is highly variable spatially and temporally. Some of the species are strictly offshore, while others may occupy both nearshore and offshore waters. In addition, some species may be suited for the open ocean or pelagic waters, while others may be more oriented to bottom or demersal waters. This can also vary between life stages of Federally managed species. Also, seasonal abundances are highly variable, as many species are highly migratory. Impacts from dredging the navigation channel would include destruction of demersal or bottom dwelling life stages, if they occurred in the disturbed navigation channel. Wetland restoration at Kelly Island would change shallow water habitat to wetlands; however, this area is eroding at up to 20 feet per year, destroying wetlands that are important nursery areas for many fish species. Many other areas of the Delaware Bay shoreline are eroding, creating more shallow water habitat in the process. Restoring and protecting wetlands has a net positive value on the aquatic environment. Beach restoration at Broadkill Beach will convert shallow water habitat to upland beach habitat. Broadkill Beach is eroding at a rate of an average of 10 feet per year and has been nourished numerous times in the last 50 years by the State of Delaware (Corps. 1996a).

Channel Deepening/Maintenance Dredging

The existing navigation channel is disturbed from maintenance dredging and/or from prop wash from boat traffic. Adult and juveniles are mobile and many would be able to move away from the dredge, but some mortality of eggs, larvae and juveniles would be expected by entrainment into the dredge.

The physical effects of dredging would be the removal of existing sediments to deepen the project area to the 45-foot design depth. Due to both the dynamics and the nature of the sediments there should be (1) negligible loss in the benthic invertebrate community as the substrate returns to a typical condition, and (2) a minor localized increase in turbidity. The depths in the work area would remain within the same depth range that has been present for over fifty years. The substrate of the channel would show little or no change subsequent to dredging. Noise generated by the project would be typical of the normal traffic of commercial and recreational vessels using the existing channel.

Typically, turbidity associated with dredging will reach background levels within an hour or less after dredging stops, dependent upon the composition of the material being dredged. Bodily injury or entrainment of species in the channel may occur as a result of failure to leave the dredge area. However, the likelihood of this scenario occurring is unlikely due to several factors: 1) dredging is accomplished in a sequential manner, resulting in continuous dredging in one zone, rather than random operations, increasing the chance of escape; and 2) noise from vessels repetitively working in one area further increase the chance of flight from the area. Therefore, given the wide distribution of EFH species and the given population density in the channel, the possibility of dredge contact or entrainment during dredging is minimal. The existing channel is well-trafficked by both recreational and commercial vessels. The disturbance created by daily operations during dredging should have no greater impact. After project construction is complete, the exposed substrate should present benthic habitat of no less quality than previously exposed substrate. For all species and respective EFHs, the impacts during dredging will be minimal. Best management practices will be used to minimize potential effects.

Channel Bend Modification

The 11 bend widenings total approximately 215.9 acres that will be deepened from an average of – 41.7 feet mlw to 46 feet mlw. The substrate is silt (143.9 acres), sandy silt (50.2 acres), and sand (21.8 acres). Since the areas to be deepened are relatively deep and no shallow water habitat (< -10 feet mlw) is present, the only anticipated impacts to managed species would be those described above for channel dredging.

Wetland Restoration at Kelly Island

Construction of the Kelly Island wetland restoration project will result in a change from shallow water habitat to wetlands and beach habitat. The benthic community of this site, which covers about 120 acres, would be eliminated and the bottom would be changed from subtidal to intertidal wetland, averaging about +5 feet MLW and beach habitat. Benthic community evaluations were conducted in this area in 1993 and 1994 and the data suggests that the area does not provide unique habitat. In 1993, 23 species were identified. The area was dominated by the bivalve *Mulina lateralis*, which accounted for 94 percent of individuals. In 1994, 39 species were identified. Dominant species included the crustacean *Leucon americanus* (66 percent) and the bivalves *Mulina lateralis* (14.6 percent) and Gemma gemma (14.1 percent). The abundance of opportunistic species is typical of disturbed environments. Also, the area in the vicinity of Kelly Island was dominated by two different species between the two years it was sampled, which is a further indication of its unstable benthic community. Kelly Island is eroding at a rate of 20 feet per year, destroying wetlands that are important nursery areas for many fish species including winter and summer flounder. Many other areas of the Delaware Bay shoreline are eroding, creating more shallow water habitat in the process. Restoring and protecting wetlands has a net positive value on the aquatic environment. The constructed beach at Kelly Island will also provide valuable horseshoe crab spawning habitat.

Beach Nourishment at Broadkill Beach

Beach nourishment at this site will convert shallow water habitat to upland beach habitat. Benthic community evaluations were also conducted in the vicinity of this site in 1993 and 1994 and the data suggests that the area does not provide unique habitat. In 1993, 51 species were identified. Dominant species included the crustaceans *Ampelisca* sp. (27 percent) and *Cerapus tubularis* (14.7 percent), and the bivalves *Mulinia lateralis* (18.2 percent) and *Nucula proxima* (12.9 percent). In 1994, 48 species were identified. Dominant species included *Ampelisca* sp. (14.8 percent), *Cerapus tubularis* (8 percent), *Nucula proxima* (41.8 percent) and the gastropod *Retusa canaliculata* (14.6 percent). Colonies of the sand builder worm (*Sabellaria vulgaris*) have been identified on rock groins and the inlet jetty within the project area. Broadkill Beach is eroding at an average rate of 10 feet per year (Corps, 1996 a). Broadkill Beach has been nourished numerous times in the last 50 years. Impacts of beach nourishment at Broadkill Beach to horseshoe crab, *Sabellaria vulgaris*, sandbar shark and winter flounder are discussed below.

Blasting in the Mixing Zone

Approximately 77,000 cubic yards of bedrock from the Delaware River, covering 18 acres near Marcus Hook, Pennsylvania (River Mile 76.4 to River Mile 84.6) would be removed to deepen the navigation channel to a depth of 47-ft mean low water. Blasting operations would occur in December and January over two consecutive years. Blasting could occur up to five days a week, but the actual blasting would only occur for a brief period each day. The following measures will be employed to protect fish during the blasting period:

The pre- and post-blast monitoring for fish including the shortnose sturgeon shall be conducted under the supervision of a principal biologist that has at least a Master of Science degree in fisheries biology or similar fields approved by the Contracting Officer. In addition, the principal biologist must have at least 3 years of experience in the estuarine/marine environment, which includes working with shortnose sturgeon, and the principal biologist must have obtained in their name the appropriate ESA permits to work with shortnose sturgeon.

Before each blast, four sinking gillnets (5.5 inch stretched mesh. 328 feet [I00 meters] long, 9.8-13.1 feet [3-4 meters] high) will be set to surround each blast area as near as feasible. These nets shall be in place for at least 3 hours and none of the nets will be removed any sooner than 1 hour before the blast. This may require ovenight sets. The nets shall be manned continuously to prevent obstructing the channel to ship traffic. Any sturgeon removed (shortnose or Atlantic) shall be tagged and released at a location approved by the NMFS.

Within 10 minutes of blast, channel nets (1-2 inch mesh) will be set during daylight hours downcurrent of the blast area and within approximately 300 feet from the blast area in order to capture and document dead or injured fish. The channel net shall have a minimum head rope length of 100 feet and should be retrieved approximately one hour later.

Surveillance for schools of fish will be conducted by vessels with sonar fish finders (with a LCD display screen) for a period of 20 minutes before each blast. The surveillance zone will be approximately circular with a radius of about 500 feet extending outward from each blast set. If fish schools are detected, blasting will be delayed until they leave.

Two scare charges shall be used at each blast. The scare charges shall be detonated in close proximity to each blast. Each individual scare charge shall not exceed a TNT-equivalent weight of 0.1 lb. The detonation of the first scare charge will be at 45 seconds prior to the blast, with the second scare charge detonated 30 seconds prior to the blast. It is necessary to employ the scare charges and conduct the surveillance surveys before each blast, as some fish have been found to recolonize the blast zone soon after a detonation.

All blast holes will be stemmed to suppress the upward escape of blast pressure from the hole. The minimum stemming shall be 2 feet thick. Stemming shall be placed in the blast hole in a zone encompassed by competent rock. Measures shall be taken to prevent bridging of explosive materials and stemming within the hole. Stemming shall be clean, angular to subangular, hard stone chips without fines having an approximate diameter of 1/2-inch to 3/8-inch. A barrier shall be placed between the stemming and explosive product, if necessary, to prevent the stemming from setting into the explosive product.

Blast pressures will be monitored and upper limits will be imposed on each series of 5 blasts. Average peak pressure shall not exceed 70 pounds per square inch (psi) at a distance of 140 feet.

Maximum peak pressure shall not exceed 120 psi at a distance of 140 feet.

Pressure will be monitored for each blast only at a distance of 140 feet.

Change in Salinity Patterns

Salinity is the concentration of inorganic salts (total dissolved solids, or "TDS") by weight in water, and is commonly expressed in units of "psu" (practical salinity units) or "ppt" (parts per thousand). By example, ocean water with a salinity of 30 ppt contains ~30 grams of salt per

1000 grams of water. The two units of measure, psu and ppt, are effectively equal for practical purposes, and the latter term, ppt, will be utilized throughout this report. The distribution of salinity within the Delaware estuary is important for a number of reasons, including its effects on habitat suitability for living resources (fish, shellfish, plant life, etc.), and its impact on human uses of the water of the estuary (industrial and municipal water supply withdrawals, groundwater recharge, etc.).

The distribution of salinity in the Delaware estuary exhibits significant variability on both spatial and temporal scales, and at any given time reflects the opposing influences of freshwater inflow from tributaries (and groundwater) versus saltwater inflow from the Atlantic Ocean. Saltwater inflow from the ocean is in turn dependent on the tidal discharge and the ocean salinity. Salinity at the bay mouth typically ranges from about 28 to 32 ppt. Tributary inflows by definition have "zero" salinity in the sense of ocean-derived salt; however, these inflows contain small but finite concentrations of dissolved salts, typically in the range of 100 to 250 parts per million (ppm) or from 0.1 to 0.25 ppt TDS.

A longitudinal salinity gradient is a permanent feature of salt distribution in the Delaware estuary. That is, salinity is always higher at the mouth and downstream end of the system and decreases in the upstream direction. The upstream limit of ocean-derived salinity is customarily treated as the location of the 0.5 ppt (or 500 ppm) isohaline. For purposes of monitoring water quality in the Philadelphia-Camden area, the DRBC has adopted the 7-day average location of the 250 ppm isochlor as the “salt front”. Because chloride ions represent approximately 55% by weight of the total dissolved ions in seawater, a “salt front” defined by a chlorinity of 250 ppm approximates a salinity of 450 ppm, or 0.45 ppt.

There is also a lateral salinity gradient present in the bay portion of the estuary, between the mouth and about RM 50, with higher salinities near the axis of the bay, and lower salinities on the east and west sides. Upstream of Artificial Island at RM 50, salinity tends to be more uniformly distributed across the channel. Under most conditions in the estuary, there is only a small vertical salinity gradient, due to the dominance of tidal circulation and mixing relative to the normal freshwater inflow. However, under prolonged high-flow conditions, such as during the spring freshet, vertical salinity gradients of as much as 5 ppt can occur in the lower bay, with corresponding smaller vertical gradients at locations further upstream to the limit of the salt front.

At any given point in the estuary between the bay mouth and the location of the salt front, the salinity of the water column will vary directly with the phase of the tidal currents. Maximum salinity at a point occurs around the time of slack water after high tide, and minimum salinity occurs at the time of slack after low. This condition reflects the significant role played by tidal currents in advecting higher salinity water in the upstream direction during flood flow, with lower salinity water being advected in the downstream direction during ebb. For periods longer than a single tidal cycle, the salinity at a given location varies in response to other important forcing functions, including the short-term and seasonal changes in freshwater inflow, wind forcing over the estuary and adjacent portions of the continental shelf, and salinity and water level changes at the bay mouth. Over longer periods (years to decades and longer), sea level changes and modifications to the geometry of the estuary also affect the long-term patterns of salinity distribution.

To illustrate the variability of salt distribution in the estuary over time, Figure 6 presents a plot of the “salt line” location within Delaware estuary, along with average daily inflow at Trenton, for the period 1 January 1998 through 30 November 2008 (10.9 years). The term “salt line” refers to the 7-day average location of the 250 mg/l (ppm) isochlor, and is used as an approximate indicator of the upstream penetration of ocean-derived salinity. In the period shown, the salt line has been as far north as RM 90 in late summer 2005, and at or below RM 40 during multiple high-flow periods in 2006, a range that exceeds 50 miles along the axis of the estuary for a period just over a decade.

Figure 7 is a histogram of the daily salt line location for the period January 1998 through November 2008, and shows that the average location over this period is about RM 71, just upstream of the Delaware Memorial Bridge and near the mouth of the Christina River in Wilmington, Delaware. Based on monthly averages, the salt line maximum penetration occurs in October (RM 81) with the minimum in April (RM 61), reflecting the typical seasonal pattern of freshwater discharge to the estuary. A general observation is that the salt line location varies directly with the volume of freshwater inflow, and is located in the twenty-mile long zone between RM 61 and RM 81 during an “average” year.

Figure 6. Salt Line Location and Trenton Inflows from 1998 to 2008.

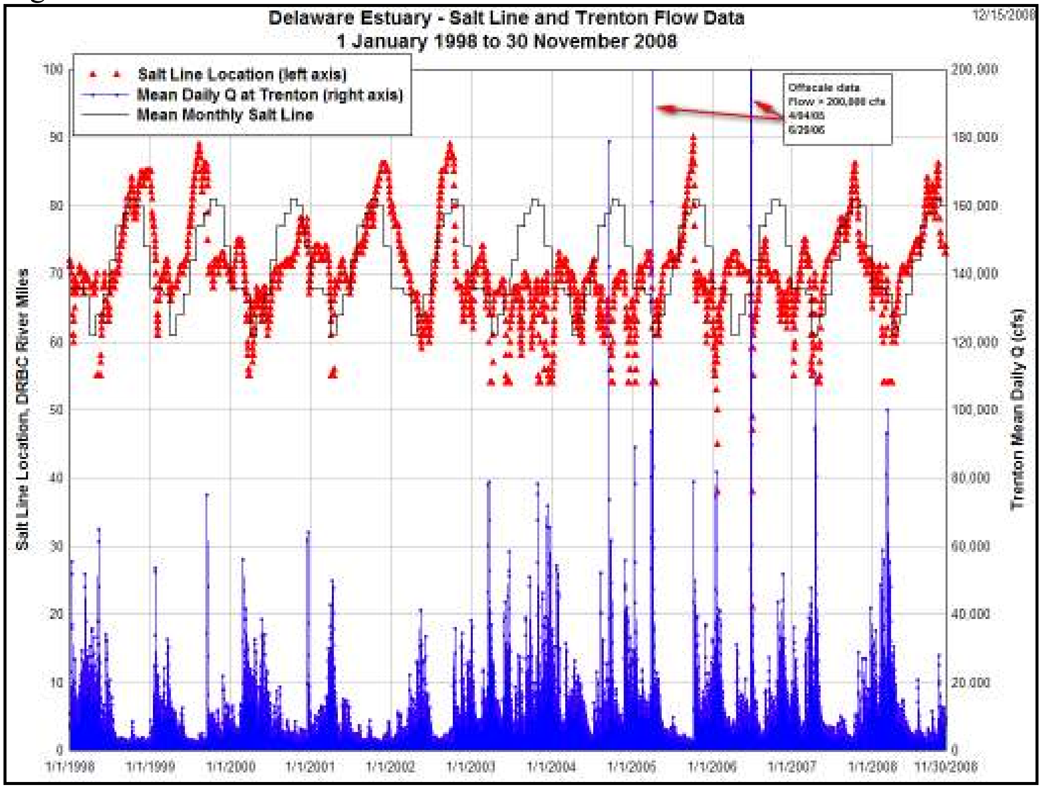
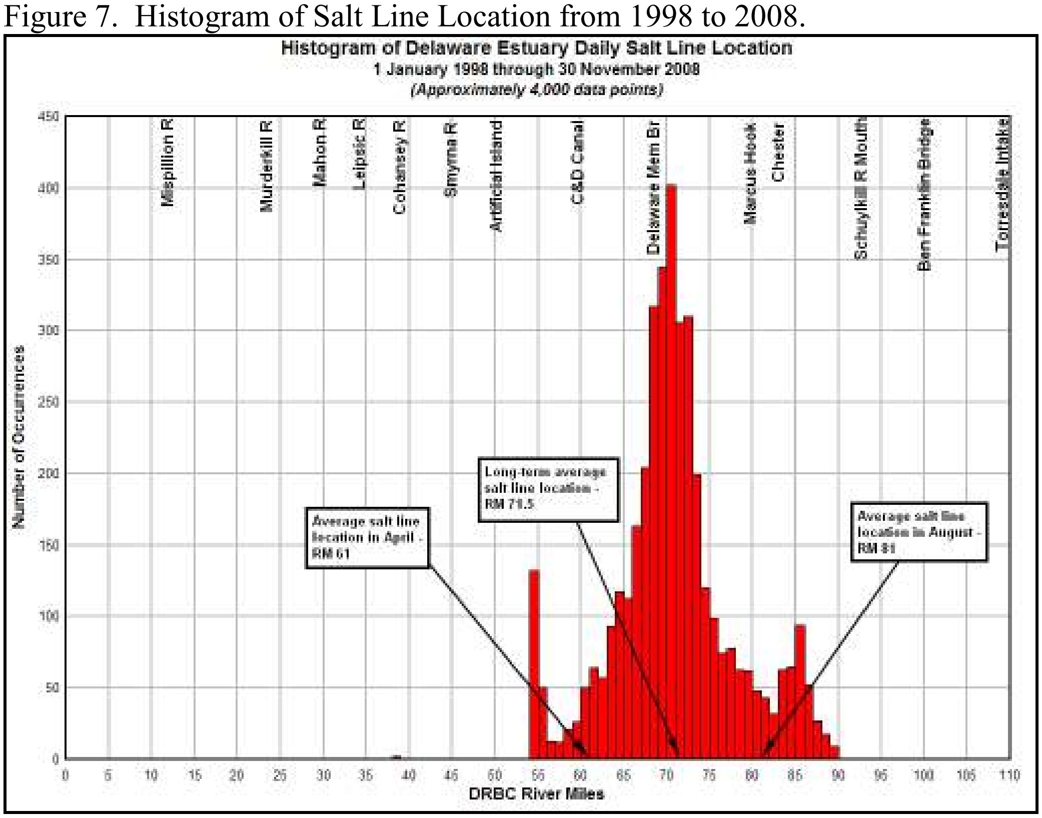


Figure 7. Histogram of Salt Line Location from 1998 to 2008.



The spatial and temporal distribution of salinity within the Delaware Estuary is an important water quality issue for a number of reasons. In the tidal region from Trenton downstream to Wilmington, Delaware River water is utilized for a number of industrial and municipal water supply purposes. The City of Philadelphia obtains its municipal water supply by withdrawal of river water at Torresdale (RM 110). Many industrial users obtain both process and cooling water from the river in the Trenton to Wilmington reach. Above RM 98, the river provides a portion of the recharge to aquifers that supply groundwater in the Camden Metropolitan area in New Jersey. This heavily urbanized area of the river is thus sensitive to increases in salinity that might affect industrial and municipal water uses, particularly under drought conditions.

The four longitudinal salinity zones within the Delaware Estuary, starting at the downstream end, are referred to as: ***polyhaline*** (18 - 30 ppt) from the mouth of the bay to the vicinity of the Leipsic River (RM 34); ***mesohaline*** (5 - 18 ppt) from the Leipsic River to the vicinity of the Smyrna River (RM 44); ***oligohaline*** (0.5 - 5 ppt) from the Smyrna River to the vicinity of Marcus Hook (RM 79), and ***fresh*** (0.0 - 0.5 ppt) from Marcus Hook to Trenton. Although these zones are useful to describe the long-term average distribution of salinity in the estuary, the longitudinal salinity gradient is dynamic and subject to short and long-term changes caused by variations in freshwater inflows, tides, storm surge, weather (wind) conditions, etc. These variations can cause a specific salinity value or range to move upstream or downstream by as much as 10 miles in a day due to semi-diurnal tides, and by more than 20 miles over periods ranging from a day to weeks or months due to storm and seasonal effects on freshwater inflows.

Salinity is also a key factor regulating the distribution of fauna and flora in the estuarine environment. Vegetation, aquatic organisms, and to a lesser degree, wildlife distribute themselves within the estuary based on their salinity tolerances. Freshwater organisms that can not tolerate high salinity are restricted to the freshwater portion of the estuary generally located above Wilmington. Marine organisms that require high salinities are restricted to the lower bay. Organisms that can function over a broad range of salinity inhabit the portion of the estuary that is within their salinity tolerance range. It should be noted that salinity is only one environmental factor that affects the distribution of organisms within the estuary, and it is necessary to consider a variety of other factors to precisely define the spatial limits of a particular species.

The U.S. Fish and Wildlife Service prepared a planning aid report in support of the Philadelphia District's Delaware Estuary Salinity Intrusion Study (USFWS, 1981). That report provides a discussion of how various components of the Delaware Estuarine ecosystem relate to salinity, and require specific salinity patterns to carry out portions of their life cycle. The following excerpt from the report characterizes the influence of salinity on the oligohaline-mesohaline portion of the estuary:

> "The information we have reviewed shows that salinity exerts strong influence on the Delaware estuarine ecosystem. Briefly, it influences the distribution of marsh plants, benthic invertebrates, fishes and certain wildlife. Relatively few aquatic species are tolerant of the entire salinity gradient from fresh water to salt water. Most species occupy portions of the gradient beyond which survival is threatened. Salinity affects seed germination and growth of marsh plants; oyster drill predation and probably MSX disease in the oyster seed beds; movement of blue crab larvae; location of blue crab spawning, nursery and mating grounds; movement of fish eggs and larvae; location of spawning, nursery and feeding grounds of fishes; muskrat production; and, waterfowl feeding and resting grounds. The overall effect of the salinity gradient is to create numerous niches, fostering wide ecologic diversity and high productivity. Literally hundreds of plant and

animal species, some with populations numbering in the many thousands, utilize the Delaware estuary."

Salinity Modeling

In order to estimate the potential for the proposed channel deepening to affect salinity distribution, the Army Corps of Engineers applied the 3-D numerical hydrodynamic model "CH3D-WES" (Curvilinear Hydrodynamics in Three Dimensions) to develop data on the movement of the salt line and the 5, 10, and 15 ppt isohalines that cover various locations in the estuary and correspond to salinities significant to various components of the estuarine ecosystem.

CH3D-WES simulates the most important physical factors affecting circulation and salinity within the modeled domain. As its name implies, CH3D-WES makes computations on a curvilinear, or boundary fitted, planform grid. Physical processes affecting baywide hydrodynamics that are modeled include tides, wind, density effects (salinity and temperature), freshwater inflows, turbulence, and the effect of the earth's rotation. The representation of vertical turbulence is crucial to a successful simulation of stratification in the bay. The boundary fitted coordinates feature of the model provides enhancement to fit the scale of the navigation channel and irregular shoreline of the bay and permits adoption of an accurate and economical grid schematization. The vertical dimension is Cartesian which allows for modeling stratification on relatively coarse horizontal grids.

The principal goal of the modeling effort was to identify and quantify any impacts of the proposed 5 foot channel deepening on spatial and temporal salinity distribution. It was considered necessary that a number of modeling scenarios be developed to represent a range of boundary and forcing conditions of potential importance to both human and non-human resources of the Delaware Estuary.

Several scenarios were identified and selected for application in the 3-D model to address the impact of channel deepening on salinity distribution and subtidal circulation in the Delaware Estuary. The selection of these sets of conditions was based on coordination accomplished through interagency workshops. The selected scenarios include:

1. The June-November 1965 drought of record, with Delaware River discharges adjusted to reflect the existing reservoir regulation plan and corresponding flows ("Regulated 1965");

2. Long-term monthly-averaged inflows with June-November 1965 wind and tide forcings; and

3. A high flow transition period, represented by the April-May 1993 prototype data set.

Each of these periods was simulated first with the existing 40 foot navigation channel, and then with the proposed 45 foot channel in place. A detailed presentation of the findings of the salinity modeling is presented in Section 5 of the July 1997 Supplemental Environmental Impact Statement (SEIS), and is not presented here. Instead, the concluding paragraphs of Section 5 are quoted.

"A fundamental conclusion from the study is that deepening the existing navigation channel from 40 feet to 45 feet will result in salinity (chlorinity) increases in the

Philadelphia area during a recurrence of the drought of record. However, the increases will not have an adverse impact on water supply. The present DRBC drought management plan, including reservoir storage added since the drought of record, prevents the intrusion of ocean salinity into the Philadelphia area in excess of existing standards [maximum 30-day average of 180 ppm of chlorides and a maximum 30-day average of 100 ppm of sodium at River Mile 98]. With the deepened channel and a recurrence of the drought of record, the maximum 30-day average chlorinity at RM 98 is about 150 ppm.

Historic groundwater withdrawals from the Potomac-Raritan-Magothy (PRM) aquifer in Camden County, New Jersey, have depressed the potentiometric surface of the aquifer system to a level as much as 100 feet below sea level in the central portion of the county. This has led to a condition in which a portion of the total recharge to the (PRM) aquifer system in Camden County is derived from Delaware River water. The present Delaware River Basin Commission drought management standard for RM 98 chlorinity is a maximum 30-day average of 180 ppm. This standard was adopted in order to limit the recharge by river water with elevated chlorinity into the PRM aquifers exposed at the bed of the Delaware River above RM 98 under low flow conditions.

Investigations of Camden County groundwater resources by the US Geological Survey (Navoy, 1996) have indicated that the rate of aquifer recharge from the river is principally controlled by groundwater withdrawals. Deepening of the Delaware River navigation channel will have a negligible effect on the recharge characteristics of the aquifer. Although the proposed channel deepening is predicted by the salinity model to increase RM 98 chlorinity with a recurrence of the drought of record, the resulting 30-day average chlorinity will still be below the present standard of 180 ppm. Transient increases in chlorinity of the river water recharging the aquifer under drought conditions will cause no loss of potability in the groundwater resource. Thus, it is concluded that the proposed channel deepening will not have a significant adverse impact on the hydrogeology or groundwater resources of Camden County, New Jersey. Increases in salinity attributable to channel deepening that could occur during a recurrence of the 1961-65 drought are unlikely to cause any additional adverse effect to environmental resources; freshwater aquatic vegetation will experience temporary decreases in distribution and productivity in the vicinity of RM 69, during a recurrence of the drought of record, but is expected to recover when the drought is over.

During normal to high flow periods with the deepened channel, oyster bed areas in the lower bay will experience increases in salinity due to steeper longitudinal salinity gradients which accompany high flow conditions. The impact of those increases on oyster production is viewed as negligible. Changes in the subtidal circulation over the oyster beds due to channel deepening will also be minimal, e.g., less than 1 cm/sec. Impacts that may occur to other environmental resources are also considered to be insignificant."

Post-SEIS Salinity Modeling

In 2003, DRBC requested additional information regarding the potential for factors other than the proposed deepening to impact salinity in the Delaware Estuary system. DRBC asked whether increased consumptive use of Delaware River water, and potential future increase in sea level, would amplify the impacts of deepening on salinity. To address these questions, the Army Corps of Engineers conducted additional simulations with the CH3D model between 2004 and

2007.

The model was applied to assess the impact on salinity of three independent scenarios, namely:

1. Delaware Bay and River channel deepening from 40 ft to 45 ft
2. Projected increased consumptive use of fresh water between 1996 and 2040
3. Projected sea level change from 1996 to 2040

The model was executed for the entire year of 1965. The year 1965 was selected because it includes the period of lowest flows and highest observed chlorinity in the vicinity of Philadelphia during the 1962-65 drought of record, which is the worst-case hydrologic regime considered for water resources planning in the Delaware Basin. Suitable prototype data sets for tide and salinity/chlorinity exist to allow meaningful comparison of observed 1965 data with model computed values. Minor model adjustments (bottom friction and horizontal diffusion coefficients) were made that improved the model's ability to reproduce observed salinity/chlorinity measurements made during the drought of record in the portion of the estuary from Philadelphia downstream to the Delaware Memorial Bridge.

The projected consumptive use input files were generated by DRBC, and a sea level rise value of 1.27 per century was adopted based on measurements at NOS tide gauges during the 20th century along the coasts of New Jersey and Delaware. Model results were saved at the Delaware Memorial Bridge, Chester, and RM 100 (Ben Franklin Bridge). Although the estuary south of the Delaware Memorial Bridge was included in the modeling, data were not saved in this reach.

These changes were first modeled individually, and then all three scenarios were modeled together. The modeling demonstrated that all three system changes – channel deepening, increased consumptive use, and sea level rise – individually cause small but finite increases in salinity in the reach between Philadelphia and Wilmington. Of the three changes modeled individually, the smallest impact resulted from the projected consumptive use, and the largest impact was from projected sea level rise. Table 2 presents the maximum instantaneous change resulting from each scenario, compared with the background range of salinity/chlorinity during the 1965 simulation period. The last row in Table 2 presents the results of the model run with all three scenarios imposed – channel deepening, 2040 consumptive use and sea level projected to 2040.

Table 2. Salinity Model Results

MODEL SCENARIO	**Location**					
	Delaware Memorial Bridge (RM 69)		**Chester (RM 83)**		**Ben Franklin Bridge (RM 100)**	
	Max Instantaneous Change, Salinity ppt	Background Range, 1965, Salinity ppt	Max Instantaneous Change, Salinity ppt	Background Range, 1965, Salinity ppt	Max Instantaneous Change, Chlorides ppm	Background Range, 1965, Chlorides ppm
Deepen Channel to 45 ft	0.25	0 to 6	0.1	0 to 1.8	10	0 to 140

Consumptive Use in 2040	0.2	0 to 6	0.1	0 to 1.8	5	0 to 140
Sea Level Rise in 2040	0.7	0 to 6	0.25	0 to 1.8	20	0 to 140
Three Scenarios Combined	1.2	0 to 6	0.4	0 to 1.8	34	0 to 140

Model results show that each of the system changes will increase the intrusion of salt into the Delaware Bay and River. The increase due to sea level rise is significantly larger than increases due to the other two system changes acting alone. The impact of all three system changes under conditions of the worst-case basin hydrology (drought of 1965) will result in salinity increases in the Delaware River as shown in Table 2, but even in aggregate do not violate the DRBC RM 98 chlorinity standard of 180 ppm chlorides.

In its 1981 Planning Aid Report, the U.S. Fish and Wildlife Service indicated that a shift in salinity zones would also shift spawning and nursery areas for estuarine fishes. Such a shift could move eggs and larvae closer to the Salem Nuclear Generating Station (RM 53), which could possibly result in greater impingement and entrainment losses. The 10 ppt isohaline, which can fluctuate naturally over a 30 mile zone of the estuary and represents a reach that provides valuable spawning and nursery habitat for a variety of fishes, moved upstream an average of from 0.0 to 1.0 miles with the deepened channel. The maximum monthly average increase in salinity within the mesohaline zone was 0.1 to 0.3 ppt. This does not represent a significant increase, and will not significantly impact the fish resources in this area.

Sediment Quality Concerns

A review of sediment quality concerns associated with the Delaware River Philadelphia to the Sea navigation channel was provided in Section 4 of the 1997 Final Supplemental Environmental Impact Statement. That information is incorporated here by reference. The review included bulk sediment analyses, elutriate sediment analyses, Toxicity Characteristic Leaching Procedure (TCLP) analyses, biological effects based sediment testing, and high resolution PCB congener analyses. Based on this review the U.S. Environmental Protection Agency commented: "These tests showed no toxicity or bioaccumulation of any significance; therefore, EPA continues to believe that there will be no adverse impacts associated with the disposal of sediments generated by the project." (USEPA, 1997). In addition, in a letter from the U.S. Fish and Wildlife Service regarding Endangered Species Act consultation for the deepening project the Service commented: "Results of chemical analyses provided within the BA indicate that contaminant loads in the sediments tested are low. The mean and range of contaminant concentrations were provided for each reach of the proposed project area. Mean contaminant concentrations fell within ranges considered to be background for soils and sediments in New Jersey. Maximum concentrations that exceed background appear to be in isolated samples, and are, therefore, limited in spatial distribution. Additionally, no demonstrable acute toxicity or bioaccumulation of sediment-associated contaminants were demonstrated in laboratory tests." (USFWS, 1996).

Since 1997, two additional sets of bulk sediment data have been collected from the channel (Versar, 2003 and 2005a). A total of 45 sediment cores were collected between Philadelphia and the Chesapeake and Delaware Canal and analyzed for inorganics, pesticides, PCBs, volatile and semi-volatile organic compounds. The results were compared to updated Residential Direct

Contact criteria developed by the State of New Jersey, and used by the State to evaluate the quality of dredged material.

In general, the post-1997 data are similar to data presented in the 1997 SEIS. The most common parameters detected in sediments are inorganic metals. Concentrations of inorganics in all 45 samples were below New Jersey residential criteria except for thallium and arsenic. Two samples had thallium concentrations (5.33 ppm and 7.24 ppm) above the residential criterion of 5 ppm. Two samples had arsenic concentrations (51.4 ppm and 37.4 ppm) above the residential criterion of 19 ppm. Thallium and arsenic, along with antimony, were the only inorganic parameters to exceed New Jersey criteria in previous sampling efforts. Overall, the relatively small number of exceedences is an indication that channel sediments are not contaminated with inorganic metals.

Organic parameters were less frequently detected in channel sediments. Only one sample had a pesticide concentration above New Jersey Residential criteria. A sample collected just below the Walt Whitman Bridge had a concentration of heptachlor epoxide of 0.074 ppm, which is slightly above the New Jersey residential criterion of 0.070 ppm. This sample and a second in the vicinity of the Walt Whitman Bridge were the only samples to exceed the PCB residential criterion of 0.2 ppm. Total PCB concentrations (sum of detected arochlors) in these two samples were 0.28 and 2.52 ppm.

The most frequently detected organic parameters were polycyclic aromatic hydrocarbons (PAHs). This was also true of previous sampling efforts. PAHs are primarily formed through combustion of fossil fuels and are expected to be found in highly industrialized and populated regions. Five PAHs were detected in sediment samples above New Jersey residential criteria. These PAHs are benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, dibenzo(ah)anthracene and ideno(123-cd)pyrene. In 2003, one sediment sample collected in the Marcus Hook range had concentrations of all five PAHs above the New Jersey residential criteria. Two other sediment samples had concentrations of benzo(a)pyrene (0.23 and 0.26 ppm) above the New Jersey criterion of 0.2 ppm. In 2005, three samples in the vicinity of the Walt Whitman Bridge or upstream of the bridge had concentrations of benzo(a)pyrene and benzo (b)fluoranthene above criteria. Two of the samples also had concentrations of benzo(a)anthracene (1.2 and 1.0 ppm) above the criterion of 0.6 ppm. Two additional samples collected in the vicinity of Wilmington, DE also had concentrations of benzo(a)pyrene (0.39 and 0.34 ppm) above the New Jersey criterion of 0.2 ppm. Overall, regarding organic contaminants, the relatively few detections above New Jersey criteria and the magnitude of the exceedences are indications that channel sediments are not a contaminant concern. The 2003 and 2005 data sets support the findings presented in the 1997 Supplemental Environmental Impact Statement. This data was reviewed by the New Jersey Department of Environmental Protection and used to support issuance of a water quality certificate for continued maintenance of the existing channel in September 2007.

In November 2004, the M/T ATHOS struck a submerged anchor while docking at the Citgo Asphalt Refinery in Paulsboro, NJ and discharged nearly 265,000 gallons of crude oil into the Delaware River and nearby tributaries (Aquatic TWG, 2007). Subsequent impact assessments included intertidal and subtidal sediment samples collected within three weeks following the spill. For subtidal sediments, the highest concentration of total PAH was 12.9 ppm in nearby Woodbury Creek. Additional sediment samples were collected 1, 3 and 10 months following the release. Based on various analyses it was determined that while there was a substantial impact on productivity in the months immediately following the spill, sediment baseline conditions (i.e., no spill-associated service losses) were reached in 14 months (NOAA, 2009). Dredging channel sediments for the deepening project will not result in any adverse impacts attributable to the M/T ATHOS event.

Important Fishery Resources within the Delaware Estuary

The following provides information on several important fishery resources within the Delaware Estuary.

Blue Crab

The blue crab supports the most valuable fishery in Delaware, with an average commercial catch of 50,000 bushels of hard shells and peelers per year; the pot fishery accounts for the majority of the total landings. A dredge fishery for blue crabs occurs from December 15 to March 30 in the lower Delaware Bay, targeting fully recruited crabs (carapace width greater than or equal to 120 mm) that overwinter in deeper waters (depth greater than 10 m) with relatively high salinity. Mature females are dominant in these waters, and make up the vast proportion of blue crabs residing in the lower Delaware Bay. At the onset of winter, mature female blue crabs migrate to the mouth of the estuary and burrow into deep-water sediments where they remain until spring. Young-of-year females (carapace width less than 60 mm) and male crabs of all size classes tend to burrow near their foraging habitat in shallow water. If a large portion of the overwintering female blue crab population utilizes the navigation channel, then dredging operations could adversely impact the winter crab dredge fishery and blue crab recruitment in the following year.

Concerns have been raised that dredging in the lower Delaware Bay (from the mouth to River Mile 32) during the winter could impact the over-wintering population of female blue crabs. The Delaware River Basin Fish and Wildlife Management Cooperative recommends a dredging restriction from December 1 through March 31 to protect over-wintering blue crabs. Stratified random blue crab surveys were conducted in January 2001 and February 2002 to provide information on crab density, abundance and population characteristics for the lower Delaware Bay that could be used to assess the relative importance of the navigation channel as habitat for over-wintering blue crabs (Verasr, 2001c and Versar, 2002).

The first year survey was conducted in lower Delaware Bay (including the Federal navigation channel) in an area extending from river mile 0 to the N 39 degree 20' parallel, excluding tributaries and shallow waters (less than 5 m). The survey area was divided into six primary geographic strata: (1) deep water at the mouth of Delaware Bay; (2) lower bay on the State of New Jersey side; (3) lower bay on the State of Delaware side; (4) upper bay on the State of New Jersey side; (5) upper bay on the State of Delaware side; and (6) the Federal navigation channel. The navigation channel was divided into four segments based on range (Liston, Crossledge, Miah Maull, and Brandywine). Sampling in the channel covered three distinct dredging categories: (1) areas previously dredged within the last 15 years for maintenance of the Delaware Bay 40-foot project; (2) areas not previously dredged but would be dredged for construction of the Delaware Bay 45-foot project; and (3) areas not previously dredged and not required to be dredged for construction of the Delaware Bay 45-foot project.

A stratified random dredge survey was conducted during January 2001 to estimate density, abundance, and size/sex composition of the blue crab population. The survey was designed to obtain separate estimates of density and abundance by sex for the Federal navigation channel, the channel bank, and the remaining areas of Delaware Bay with depths greater than 1.5 m. A total of 105 stations were sampled in the standard stratified random survey, with 30 stations allocated to the channel, and 15 stations to each of the other strata. In addition, 30 stations were sampled as a test for differences in density between the bottom of the channel and the channel bank. Sampling was conducted from a commercial fishing vessel equipped with a dredge (4.3 m wide) widely used in the Delaware winter blue crab fishery. The dredge was generally hauled for 2 minutes along the bottom at a speed of 3 knots. The towing distance (in meters) for all hauls was measured by GPS, and depth was recorded from acoustic readings. The area swept for each haul was estimated as the towing distance multiplied by the width of the dredge. For each haul, the number of blue crabs was recorded, and information on carapace width to the nearest mm, sex, maturity stage, and overall condition was collected for each specimen. Live crabs and dead crabs were tallied separately by sex to provide information on winter mortality. The Catch-Per-Unit-Effort (CPUE) for each haul was standardized to number of crabs per 1,000 square meter area swept. A bottom sediment sample was collected at each station to determine grain size.

On average, it was estimated that 22% of the crabs present in the path of the survey dredge were caught. After statistically adjusting for the dredge catching efficiency, the density of blue crabs in the Federal navigation channel was estimated at 62.0 live crabs per 1,000 square meters (251 crabs per acre), as compared to 51.4 live crabs per 1,000 square meters (208 crabs per acre) for the entire study area. There was no significant difference between these two density estimates. The winter mortality appeared to be substantial, with dead crabs constituting about 20% of the total. The total winter population was estimated at 71.46 million live crabs for the entire study area, and 1.1 million for the section of the Federal navigation channel included in the survey. Only a small fraction (1.6% or less) of the blue crab population in lower Delaware Bay resided in the navigation channel during the survey. The absolute abundance of fully recruited crabs (120 mm and greater carapace width) in the study area was 60.2 million crabs, and 1.05 million for the navigation channel (1.7% of the total). A significant number of age 0 crabs and adult males (age 1+) are likely to over-winter in the upper Delaware Bay and its tributaries, and were not sampled effectively in this survey. This portion of the stock is unlikely to be affected by the deepening project, and therefore was not a target for the survey.

Blue crab sampling in the Federal navigation channel covered bottom habitats that have previously been subject to Corps of Engineers regular maintenance dredging, as well as areas that have not previously been dredged. Although not statistically significant, the estimated mean absolute density in previously dredged areas (2.7 crabs per 1,000 square meters) was substantially lower than the mean density in areas that have never been dredged (65.9 crabs per 1000 square meters). This suggests that frequent dredging may result in less suitable habitat for over-wintering blue crabs.

For a section of Miah Maull Range that could be dredged during the winter (3.7 km in length and 1.13 square km in area), the estimated abundance of live crabs across size and sex groups was 70,038 crabs based on the mean density in the entire channel. The number of crabs in the impacted area constituted about 6% of the live crabs in the channel and 0.1% of the crabs in the entire lower Delaware Bay survey area (based on the overall mean density of crabs in the channel). Sampling stations in the Miah Maull Range alone gave an estimate of 2.3 live crabs per 1,000 square meters or a total of 2,594 live crabs in the impacted area.

The second year survey was conducted in the same portion of Delaware Bay as the first year. The survey area was divided into the same six primary geographic strata: (1) deep water at the mouth of Delaware Bay; (2) lower bay on the State of New Jersey side; (3) lower bay on the State of Delaware side; (4) upper bay on the State of New Jersey side; (5) upper bay on the State of Delaware side; and (6) the Federal navigation channel. The sampling intensity in the navigation channel was enhanced relative to the first survey; taking into account more detailed and spatially referenced information about previous and planned channel dredging. Again, sampling in the channel covered three distinct dredging categories: (1) areas previously dredged within the last 15 years for maintenance of the Delaware Bay 40-foot project; (2) areas not previously dredged but would be dredged for construction of the Delaware Bay 45-foot project; and (3) areas not previously dredged and not required to be dredged for construction of the Delaware Bay 45-foot project. The previously dredged category was further divided into three categories: (1) dredged between 1991 and 1995, (2) dredged in 1996, and (3) dredged between 1999 and 2001. These three sub-categories of the previously dredged area were of approximately equal size. In total, 25 previously dredged plots were defined for the Brandywine, Miah Maull, Crossledge and Liston navigation ranges. Survey methodologies were the same as the first year.

Again, it was estimated that 22% of the crabs present in the path of the dredge were caught. After statistically adjusting for the dredge catch efficiency, the density of blue crabs in the Federal navigation channel was estimated at 3.60 live crabs per 1,000 square meters, which was a significantly lower density than the estimated 21.87 live crabs per 1,000 square meters for the entire survey area. The density of blue crabs overall as well as for the Federal navigation channel was also significantly lower than the first year survey (51.4 and 62.0 live crabs per 1000 square meters, respectively). Sections of the channel that had been previously dredged had a density of 0.96 live crabs per 1000 square meters, as compared to 3.96 crabs per 1000 square meters in sections of the channel that had never been dredged. There was no significant difference between these two density estimates. Only a small fraction (0.22%) of the blue crab population in the lower Delaware Bay survey area resided in the Federal navigation channel during the winter survey (0.13% for the sections that could be dredged during the winter). The winter mortality during the second year survey was negligible. The winter population was estimated at 30.37 million live crabs for the entire survey area, and 66,977 crabs for the section of the navigation channel included in the survey. The absolute abundance of fully recruited crabs (120 mm and greater carapace width) in the entire survey area was 19.77 million crabs, and 47,021 crabs for the navigation channel (0.24% of the total).

For the section of the channel that would require dredging (9.86 square km in area, revised up from the first year survey) the estimated density was 4.02 crabs per 1,000 square meters, and the absolute abundance of live crabs across size and sex groups was 39,635 crabs. The number of crabs in the potentially impacted area constituted about 59% of the live crabs that were over-wintering in the Federal navigation channel, and 0.13% of all crabs over-wintering in lower Delaware Bay.

The surveys indicated that in the portions of the Federal navigation channel that could be dredged during the winter, the percentage of blue crabs likely to be impacted would be very small relative to the entire population of crabs over-wintering in Delaware Bay (less than 0.2%). While this would not likely have a significant impact on the total blue crab population in Delaware Bay, it could result in the loss of 40,000 to 70,000 live crabs. Due to the commercial and recreational importance of the blue crab in Delaware Bay, the selected plan for channel deepening in this portion of the project is to avoid the blue crab over-wintering period (December 1 through March 31). By observing this time of year dredging restriction there will be no significant impact to the blue crab population.

Horseshoe Crab

The largest population of spawning horseshoe crabs in the world is found in Delaware Bay. The eggs of spawning horseshoe crabs provide a critical food source for the thousands of shorebirds that migrate through Delaware Bay each spring. For some shorebird species migrating to their arctic nesting grounds, the stopover on Delaware Bay beaches to feed on horseshoe crab eggs may represent the most critical part of their annual reproductive cycle. Migrating shorebirds have been shown to make body weight gains of 40%, or more, during their two to three-week stopover on Delaware Bay beaches in May.

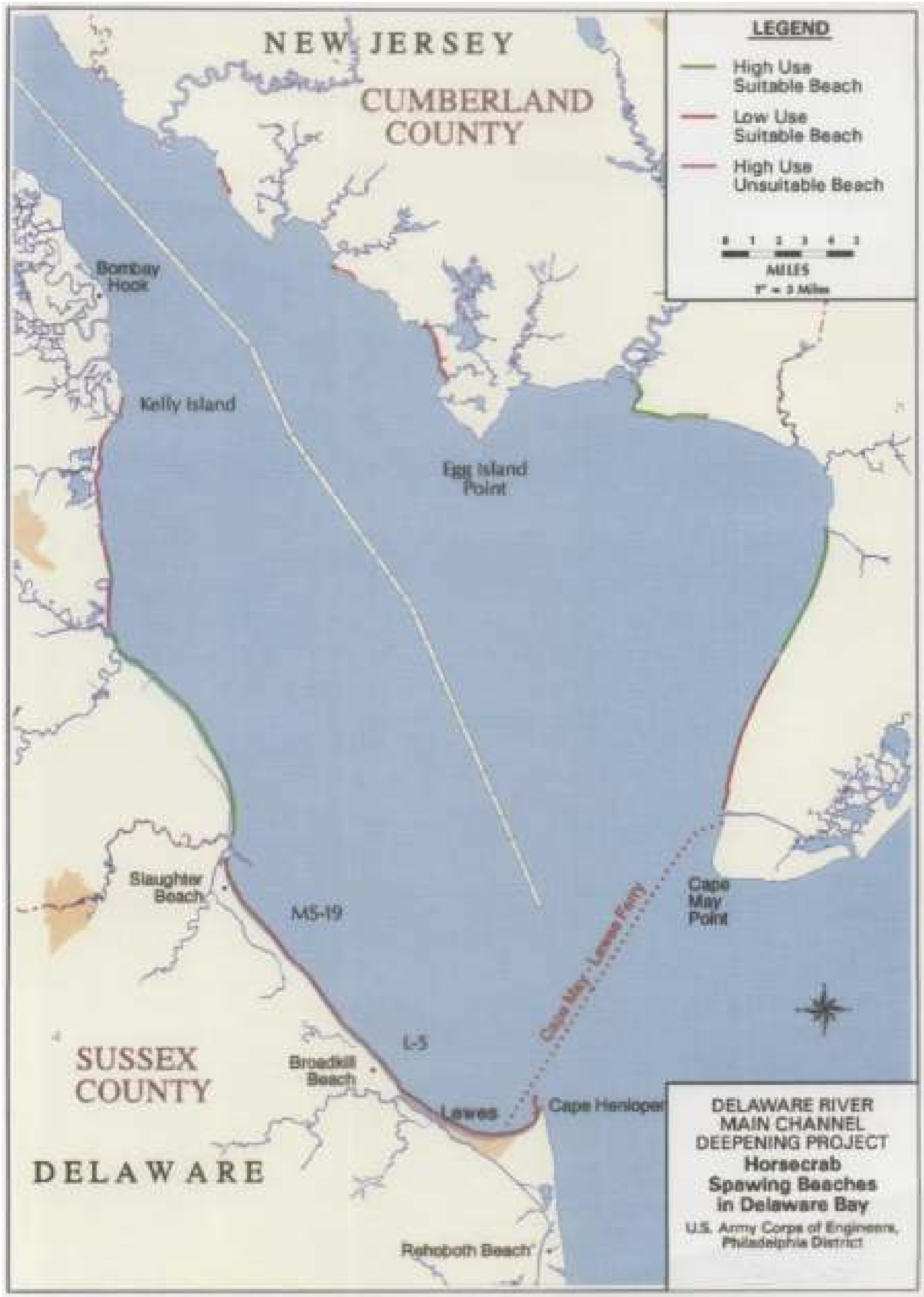
Each spring adult horseshoe crabs migrate from deep water in the Delaware Bay and the Atlantic continental shelf to spawn on Delaware Bay Beaches. Spawning generally occurs from April to July, with the peak spawning activity occurring on full moon high tides in May and June. Horseshoe crabs deposit their eggs in the upper portion of the intertidal zone in clusters approximately six to eight inches below the surface. The average cluster contains between 3,000 and 4,000 eggs. Clusters are deposited below the feeding zone of shorebirds. However, many of these clusters become dissociated before the eggs hatch, and their constituent eggs are dispersed through beach sediments, toward the surface.

Optimal spawning beaches may be a limiting factor on the horseshoe crab population. Figure 8 depicts the relative importance of Delaware Bay shoreline to spawning horseshoe crabs. Horseshoe crab reproductive success is greatest under the following conditions: 1) the egg clusters are moistened by water with salinity of at least eight parts per thousand; 2) the substrate around the egg clusters is well oxygenated; 3) the beach surface is exposed to direct sunlight to provide sufficient incubation; and 4) the slope of the beach is adequate for larvae to orient and travel downslope to the water upon hatching. These conditions are found on sandy beaches along the lower portion of Delaware Bay.

To some extent, horseshoe crabs appear to come ashore wherever they happen to be when full moon high tides occur. Horseshoe crabs can tolerate a wide range of physical and chemical environmental conditions, and will spawn in less suitable habitats if ideal conditions are not encountered. Therefore, the presence of large numbers of horseshoe crabs on a beach is not necessarily an indicator of habitat suitability. However, it also appears that horseshoe crabs can detect hydrogen sulfide, which is produced in the anaerobic conditions of peat substrates, and that horseshoe crabs actively avoid such areas. It is known that shoreline areas with high concentrations of silt or peat are less favorable to horseshoe crabs because the anaerobic conditions reduce egg survivability.

Beach slope is also thought to play an important role in determining the suitability of beaches for horseshoe crab spawning. A slope of between seven and ten degrees at the rack line (mean high

Figure 8 Horseshoe Crab Spawning Beaches in Delaware Bay



water plus wave runup) is thought to be optimal. Horseshoe crabs generally travel dowslope after spawning and appear to become disoriented on flat areas.

In addition to the intertidal zone used for spawning, horseshoe crabs also use shallow water areas such as intertidal flats and shoal water as nursery habitat for juvenile life stages. Adult horseshoe crabs forage in deep water habitat during most of the year, except during the breeding season when they move into shallow and intertidal water.

Annual surveys of Delaware Bay horseshoe crab spawning activity appear to indicate an overall decline in the horseshoe crab population in recent years. The surveys are useful in documenting relative utilization of various shoreline segments by spawning horseshoe crabs. For example, the survey data indicate declining numbers of spawning horseshoe crabs on beaches experiencing the highest erosion. Other investigations have shown that harvesting of horseshoe crabs during their critical reproductive period may have had an adverse impact on the population, resulting in a significant decrease in abundance between 1991 and 1995. The horseshoe crab requires nine to eleven years to reach sexual maturity. This increases the risk of serious adverse impact to the horseshoe crab population due to harvesting. Reduction in spawning habitat due to erosion coupled with harvesting may seriously impact the ability of the population to recover. In 2008, the State of New Jersey passed legislation that bans the harvest of horseshoe crabs in New Jersey. The State of Delaware has placed restrictions on harvesting.

Material dredged from Delaware Bay for construction of the deepening project would be used for shoreline restoration projects at Kelly Island and Broadkill Beach. These areas are known to attract shorebirds and spawning horseshoe crabs. These projects are expected to increase the amount and quality of horseshoe crab spawning habitat, significantly improving the habitat quality for both horseshoe crabs and shorebirds. In order to determine whether the completed shoreline restorations have benefited species, it is necessary to collect and analyze quantitative and qualitative baseline data on horseshoe crab egg density prior to construction.

Currently an environmental window exists that prevents construction (i.e. sand placement) to take place from April 15 to August 31 to prevent impacts to spawning horseshoe crabs. This window follows the recommendations of the Atlantic States Marine Fisheries Commission's *Interstate Fishery Management Plan for Horseshoe Crab*. This window along with other recommended restrictions for the Atlantic sturgeon and over-wintering blue crab leaves only the first two weeks of April for construction. Site-specific information was collected to evaluate the value of Kelly Island and Broadkill Beach to the horseshoe crab and the impact of sand placement within the April 15 to August 31 closure window.

A study (Weber, 2002) was conducted during 2001 to estimate the amount of potential horseshoe crab spawning habitat that exists at each site, to:

- Sample horseshoe crab egg densities at these sites,
- To compare those egg densities to egg densities on other horseshoe crab spawning areas examined on the Delaware Bay coast in Delaware during the same period.
- The study was conducted on Kelly Island and Port Mahon (both in Kent County), and Broadkill Beach (Sussex County), in Delaware during the summer of 2001.

The following summarizes the efforts conducted.

Kelly Island is not actually an island, but rather a marshy peninsula lying between the Mahon River and Delaware Bay. The southern part of Kelly Island, near the mouth of the Mahon River, is the area considered for restoration. The shoreline runs more-or-less true north. At low tide, most of the shoreline consists of irregular, vertical peat "cliffs", ranging in height from ca. 0.5–1.3 meters above low water. The high ground consists of compacted mud and peat. There are few locations where the sandy areas of upper beach grade smoothly down to the low water line. The upper edge of the beach is separated from the background marsh by a variable wrack line, consisting mostly of coarse vegetable detritus, deposited during periods of storm flooding. Bayward from this storm wrack line, and running irregularly along beside it, is a discontinuous band of wave-deposited sand of varying depth, covering the mud and peat substrate. Depth of this band ranges from approximately 40 cm at the upper edge to 2 cm at the lower edge. The band ranges in width from 2.1 m (7 ft) to 8.5 m (28 ft), and in all but a few narrow places, is discontinuous with the tide flats, being separated from the low water line by variable expanses of mud and peat substrate which are well above the low water line. All egg clusters and eggs found on this beach were in this band of sand. The two study transects sampled on Kelly Island during the 2001 study were "North", and "South", whose upper (high beach) ends were located at N39°12.679', W075°23.913' and N39°12.431', W075°23.849', respectively. Approximate distance between the two transects was 418 m (1,373 ft). These transects were selected, after a preseason site assessment, as being representative of the other sandy sections examined along that shoreline. Owing to an error in communication, both transects were located beyond the northern boundary of the proposed restoration project. This was not discovered until after samples had all been collected and processed.

Port Mahon beach has a northeasterly-oriented Delaware Bay shoreline. A sand road closely parallels the shoreline. The southern midsection of the beach has several sections of vertical metal breakwater, which persist from early attempts to protect the roadway. Breakwater sections parallel the shoreline 1–2 m out past the low tide line. The road is separated from the water by a variable band of riprap, which consists principally of boulders in the 30 – 120 cm (1 – 4 ft) size range. The lower edge of the riprap runs variously up and down through the intertidal area. In some places the lower edge of the riprap reaches out nearly to the low tide line. In other cases the lower edge rises somewhat above the middle part of the intertidal area. At lunar tides, water rises completely over some sections of riprap, and wave action erodes the roadway. As a result, the road is subject to continual grading and repair, with additional sand being added several times each year. Sand from this erosion and subsequent replenishment migrates downslope through the riprap, to create the sections of sandy beach upon which the horseshoe crabs spawn. On the bay side of the riprap, the beach contains varying amounts of smaller (brick size) miscellaneous chunks of macadam, masonry rubble, etc., applied long ago in attempts to stabilize and maintain the road. This trash material, together with random layers of shell, is variably covered with sand. The color and size uniformity of the sand particles along the riprapped beach areas suggest that most sand present is the result of erosion from the material used to repair the road. Much of what appears to be sandy beach is actually shallow sand underlain by clay hardpan, dense layers of shell, or miscellaneous trash material, and is generally unsuitable for spawning. Female horseshoe crabs seldom spawn in situations where the sand is not at least deep enough to nearly cover their bodies, approximately 10 cm (4 in). The two study transects sampled on Port Mahon during the 2001 study were "North", and "South", whose upper (high beach) ends were located at N39°11.114', W075°24.071' and N39°10.794', W075°24.297', respectively. Approximate distance between the two transects was 671 m (2,203 ft). These transects were used for the study because they have been sampled in similar studies each year since 1998. They were selected in 1998 because they had the deepest, most uniform layers of sandy sediment along the Port Mahon shoreline.

Broadkill Beach differs from the other beaches studied, being a wide, continuous band consisting almost entirely of clean sand and small (<2 cm) gravel. Sediment depths are greater than 30 cm in most sections. The beach is currently protected by a series of regularly-spaced breakwater structures extending from high on the beach, out into the water at right angles to the shoreline. Shoreward, the beach is backed by varying widths of sparsely vegetated dunes, and a dense residential area. This beach is the southernmost of the beaches studied and is approximately 42 km (26 miles) from Port Mahon. The two study transects sampled on Broadkill beach during this study were "North", and "South", whose upper (high beach) ends were located at N38°49.961', W075°12.958' and N38°49.713', W075°12.692', respectively. Approximate distance between the two transects was 577 m (1,894ft). These transect sites were selected after a preseason assessment of the entire beach frontage. They were visually representative of all frontage examined, and were reasonably close to public access points.

In Delaware Bay, *Limulus* spawning activity seems to be more intense during the full and new moon tides. During the 2001 spawning season, full moon tides were on May 7, June 5, and July 5, and new moon tides were on April 23, May 22, and June 21. Beaches were sampled 2–4 days after each of these tides. For each sampling date, two transects which were at right angles to the waterline were sampled. Upper (high beach) transect endpoints were located by reference to permanent visual markers, and recorded as GPS readings, and the same section of beach was sampled on each date. All transects were within the intertidal zone, where spawning activity is more concentrated.

On sample dates, 25 evenly-spaced core samples were collected along each transect. Each transect spanned 83% of the distance from the nocturnal high tide wrack line down toward the foot of the beach, where the flat began. The nocturnal high tide wrack line was used as the upper end of transects because nocturnal tides around the new and full moons (when spawning is believed to be heaviest) are higher on the beach than diurnal high tides of the same period. Although intertidal beach spans varied at the points where transects were located, the 25 sample cores along each transect were kept evenly, thus proportionally, spaced across the sample distance by use of transect lines made from bungee cord. These lines were marked off into 25 equal units of distance. Bungee cord lines can be stretched to fit beaches of varying widths, and since the marks spread apart at the same ratio as the line is stretched, cores are always equally spaced across the span to be sampled.

Sample cores consisted of beach sediment cores, 5.7 cm (2.25 in) in diameter x 20 cm (8 in) deep. The 20 cm depth of the sample cores spans the reported range at which most egg clusters are placed during spawning. Surface area (cross section) of each core was 25.65 cm2, giving a total cross section of the 25 cores taken per transect of 641 cm2. After each core was lifted, it was separated into two fractions: 0–5 cm and 5–20 cm depth. This was done by sliding a sheet metal divider through a transverse slit in the corer, located 5 cm from its top end. The divider was held in place until the lower, 5–20 cm, portion of the core had been dumped through a screen into a sample bucket, and then was removed so the 0–5 cm portion could be put through a screen into a second bucket. These core fractions are of interest because shorebirds forage in the surface sediments, while the clusters are deposited somewhat deeper. Knowledge of egg numbers present in the 0–5 cm part of a beach is therefore useful in estimating how many *Limulus* eggs are potentially available for shorebird use. Core sample fractions from each transect were combined into the appropriate bucket as they were collected, and all sediment material collected was processed to extract the eggs. When *Limulus* eggs are laid, they adhere together in tight clusters, and they continue to adhere tightly to each other during the first weeks of development. One, or more, tight aggregations of eggs was recorded as a single cluster. Thus, a single 20 cm core could have up to two clusters: one each from the 0–5 cm and 5–20 cm fractions. After being recorded, clumps were broken apart into the appropriate sample container, and their component eggs included in the final egg volume values. The 25 sample cores from a single transect (0–5 cm and 5–20 cm fractions, considered together) had a total volume of approximately 13.3 liters (3-1/2 gallons).

Samples were processed at the Delaware National Estuarine Research Reserve Center, on Kitts Hummock Road, south of Dover, DE. Eggs were separated into smaller, greenish undeveloped eggs ("eggs") and larger, visibly embryonated eggs ("embryos"). Only viable eggs were quantified. It is not necessary to also quantify embryos and trilobite larvae, because the eggs take sufficient time to develop that they are present in the beach for at least two sample periods before they hatch. When sample egg numbers were small, direct counts were made. When egg numbers were too great for direct counting to be efficient, the extracted eggs were measured volumetrically, using standard graduated cylinders, and a total egg count was estimated using an average egg value of 178 eggs per ml.

The following provides the project leader for this effort, Dr. Weber's thoughts and assessment of the situation at each location based upon the supplemental information gathered as a result of the the 2001 monitoring:

Kelly Island: Larvae of several species of flies and beetles (personal observation) attack *Limulus* egg clusters in the beach from approximately the middle of the intertidal zone up to the nocturnal wrack line. Most such infestations are found in the upper part of this span, and <5% of egg clusters seem to be infested (personal observation). When their development is complete, larvae pupate in the beach sediment near where they fed and grew. When adults emerge from the pupal stage, they burrow to the surface during low tide, leaving characteristic exit holes on the beach surface. Exit holes above the current tide range persist until destroyed by rain, lunar tides, human footprints, etc. Thus, presence of these insect emergence holes on the surface is evidence of *Limulus* egg clusters below, and, by extension, indicates sections of beach frontage where spawning has taken place. On Kelly Island, the presence of these insect emergence holes were used as indicators of frontage where *Limulus* spawning had occurred.

I walked 2,203 m (7,234ft) of frontage on this shoreline, to determine the amount of spawning habitat present. I began at the southern tip of Kelly Island, at the first section of sand with sufficient depth for spawning (N39°11.577', W075°23.781'), and continued northward along the storm wrack line to N39°12.872', W075°23.855. I used a GPS unit to record the lengths of sand stretches having sufficient depth for spawning. Center widths of these stretches were measured with a tape, so estimates of their surface areas could also be calculated. There were 901 m (2,957ft) of spawning habitat along this 2,203 m (7,234') of bay frontage. This represents 40.8% of the length I examined. The combined area of these sections of spawning habitat was 0.39 hectare (0.96 acre). The 2001 estimated egg load for the 901 m spawning frontage of the 2,203 m examined was 3.2 x 109 eggs.

Owing to the error mentioned earlier, the span of shoreline I examined extended from near the present south tip of Kelly Island to considerably north of the proposed restoration project. It was possible to calculate the percentage of spawning habitat that was within the limits of the proposed project. There were 933 m (3,062ft) of shoreline from the southern tip of Kelly Island to the northern limit of the proposed project. Within this span, there were 466 m (1,531 ft) of spawning habitat. This represents 49.9% of the span I examined that was within the limits of the proposed project. The combined area of the sections of spawning habitat within this span was 0.20 hectare (0.49 acre). The 2001 estimated egg load for the 466 m spawning frontage of this part of the shoreline was 0.83 x 109 eggs.

The finished bay frontage of the proposed project would be approximately 1,522 m (5,000ft). Length of bay shoreline of the completed project would then be 1.6 times greater than the length of shoreline south of the project boundary in 2001. When the project is completed, the spawning frontage would no longer consist of intermittent shallow sandy sections separated by variable spans of peat, as in 2001. Instead, the 466 m (1,531ft) of intermittent spawning habitat present in 2001 would be replaced with approximately 3.25 times as much *continuous* spawning frontage, comprised of sand deeper than ca. 1 m.

This is the first time Kelly Island has been evaluated as a *Limulus* spawning site. Judging from the evidence of a rapidly eroding shoreline—both on-site, from aerial photographs, and from the relevant USGS Quadrangle (1956)—the spawning habitat I evaluated in 2001 will very likely be altered by erosion before the next spawning season. Indeed, the impression gained from repeated sampling on the beach, and walking along the storm wrack line, is that this shoreline is not at all a constant or consistent spawning area. Some indication of recent changes along this shoreline can be obtained by simply noting the westward displacement of the sandy spawning areas I found in 2001 from the stretches of sand shown in a 1997 aerial photograph. The rate of erosion along this frontage has been variable, as shown by the varying distances between lines indicating 2001 spawning habit, and the sandy stretches present in 1997.

At my request, personnel with the Philadelphia office of the U.S. Army Corps of Engineers examined their aerial photographs and records of this area to provide me with an estimate of the rate at which this shoreline has been eroding. Their estimate is that the Bay shore of Kelly Island has been eroding westward for at least the last 100 years, at an average rate of 6 m (20ft) per year. The earliest aerial photograph of the area in their files was made in 1926. During the 75 years since, the shoreline has eroded westward approximately 457 m (1,500ft). By comparison of the 1926 aerial photograph with aerial photography of the same area done in 2001, their estimate is that the tip of Kelly Island has eroded northward approximately 487 m (1,600ft) during the same period.

It seems likely that some stretches of the Kelly Island shoreline with sand deep enough to be suitable for spawning in 2001 will still have enough sand next year. However, it is also likely that some stretches of shoreline suitable for spawning in 2001 will not be suitable next year. Further, some sections without any sand, or without a suitable depth of sand in 2001, could possibly have enough sand next year to support spawning. These are reasonable beliefs when the stretches of spawning habitat I found in 2001 are compared to the stretches of sand visible on the 1997 aerial photograph upon which they are plotted. Stretches of spawning habitat appear and disappear in response to continuing erosion of the shoreline. With reference to the 1997 photograph, in some places long stretches of sand present then are now gone. Other sandy spawning areas I found along those same sections of shoreline in 2001 are reduced in total length from stretches of sand visible in the photograph. Along some other sections of the shoreline, where no sand was visible in 1997, there was enough sand present in 2001 that spawning occurred.

Such comparisons must be made tentatively because the sandy stretches visible in the 1997 photograph were not checked to see how much spawning occurred on them. For Kelly Island, there is only the 2001 *Limulus* egg sampling and spawning habitat evaluation data, coupled with the understanding that spawning only occurs on sandy substrates. I have not observed *Limulus* to spawn in mud or peat substrates on any beach I have studied in Delaware. My experience in sampling Delaware beaches over the past five years is that they also do not spawn on beaches with only a shallow layer of sand (< 10 cm) over mud or peat. For this reason, stretches of sand shown in an aerial photograph do not necessarily indicate suitable spawning habitat.

Port Mahon: The spawning habitat along the Port Mahon shoreline is discontinuous, being interrupted by stretches of riprap and rubble. Along much of the shoreline, the high tide wrack line either falls within the area spanned by riprap, or actually reaches onto the roadway. Thus, it was not possible to use insect emergence holes to verify that spawning had occurred on a particular section. Instead, for this beach I relied on observations made during low tides over the 2001-spawning season. These included stranded males, "buried" pairs, and "nests" left when females dug out after spawning. These observations were easily made each time I sampled the beach, since the roadway parallels the high water line over most of the beach's length. I verified these observations by walking all sandy sections.

I examined the entire 1,672 m (5,491 ft) frontage of the beach at low tide, to determine the amount of spawning habitat present. I began at the southern end of the beach (N39°10.654' W075°24.491') where a culvert passes under the road, and continued northerly to N39°11.358', W075°23.909' at the bait store. I used a GPS unit to record the waterline lengths of sand stretches with sufficient depth for spawning. Center widths of these stretches were measured with a tape, so their approximate surface areas could be calculated. There were 450 m (1,478ft) of spawning habitat along the beach. This represents 26.9% of the total length of Port Mahon beach. The combined area of these lengths of habitat was 0.44 hectare (1.08 acre). The amount of spawning habitat on this beach has remained essentially the same since I examined it in 1999. At that time, total area of spawning habitat was 0.39 hectare (0.96 acre), and 28.5% of total beach length. The 2001 estimated egg load for the 450 m spawning frontage of this beach was 22.3 x 109 eggs.

Typically, Port Mahon transects have been among the top transects for total numbers of *Limulus* eggs. Season total egg numbers for the beach have ranged between 400,000 and 500,000, while per-transect season total values have been 174,000 or higher. The 2001 total egg values from Port Mahon transects S and N, 268,000 and 233,000 respectively, were considerably higher than from any other transect sampled in a parallel study of other Delaware beaches done that same season. The next highest 2001 egg total observed was from Kitts Hummock S (135,000 eggs). In 2000, total egg values from Port Mahon transects N and S were 174,000 and 229,000, respectively. These were less than the value observed on Ted Harvey S (312,000) that year. The 1999 Port Mahon transect totals were both higher than any others, with the next highest 1999 total being Ted Harvey S (140,000).

Comparing the *Limulus* egg data from Port Mahon beach with similar data collected on other beaches sampled in this, and earlier, studies is problematic. For example, the approximately mile long frontage of Port Mahon contains a rather small percentage of shoreline where there is sufficient sand to allow spawning, and where coupled *Limulus* pairs come up to the water's edge. While other beaches generally provide a meter of spawning beach for each meter of shoreline, this is definitely not the case at Port Mahon. It seems probable that female *Limulus* in the waters along Port Mahon beach are forced to concentrate into the few areas where they can spawn. This seems unlikely to be the case on most other beaches where shoreline and suitable spawning habitat are essentially equal. While the N and S transects typically have high cluster and total egg counts, these may be high simply because individuals spread along the Port Mahon shoreline are forced to come to the same few locations suitable for spawning. This could account for the high cluster counts and total egg numbers observed there. However, this concentration effect is partly offset by the fact that *Limulus* are legally harvested from Port Mahon beach two days a week, during the spawning season.

Personal observations, and discussions with those harvesting, suggest that females coming onto the beach to spawn are the primary catch. These potential spawners are taken before they have a chance to lay eggs, since females full of eggs are more desirable as bait, their intended use. No data are available on the percentage of spawning females harvested from this beach each season, but the favored places to harvest are the few spawning areas, which include areas surrounding both the N and S transects. A further confounding factor for Port Mahon spawning areas is the fact that large numbers of *Limulus* adults, of both sexes, become accidentally wedged into interstices between rocks of the riprap shoreline erosion barrier. Some individuals are trapped during each spawning event. Many of these animals become so firmly wedged between rocks that they cannot get free. Gulls prey on the more accessible individuals; the others die of exposure or starvation.

Broadkill Beach: The entire length of this beach is one continuous, unbroken stretch that is visually similar with regard to sediment size, slope, and exposure to the Bay. For this reason, I equated spawning habitat with shoreline length. On this beach it was not possible to utilize insect emergence holes as indicators of spawning because apparently too few clusters were spawned there to attract flies. Even if heavy spawning had occurred, and flies had emerged in considerable numbers, the human foot traffic along the upper part of this beach would have obliterated them from many areas.

The area I evaluated began at N38°50.347', W075°13.493' and continued southward to N38°48.408', W075°11.397', at the boundary with Beach Plum Island Nature Reserve. Total frontage length, 4,723 m (15,506'), was determined by measurements taken from beach restoration project plans provided by USACE personnel. At 13 locations distributed along the frontage, I measured beach width from the nocturnal tide wrack line down to the foot of the beach slope. Widths for Broadkill beach ranged from 11.9 m (39') to 16.1 m (53ft), with an average width of 14.4 m (47ft). Frontage length of the beach was multiplied by the average width value to estimate the amount of spawning habitat present. The full length of shoreline consisted of sandy sediments, which appeared suitable for *Limulus* spawning. The potential spawning habitat on the beach was 6.4 hectares (15.8 acres). The 2001 estimated egg load for the 4,723 m of spawning frontage on this beach was 0.25 x109 eggs.

In terms of beach slope and sediment size distribution, the entire shoreline of Broadkill Beach appears to be equally suitable for spawning. However, only low numbers of eggs were found there during this study. It is unclear why this is so, although I usually found the wave height, and corresponding surf, to be greater than found on more northerly Delaware beaches on the same day, and within an hour or two. Waves from onshore wind reduce, or prevent spawning. This surf difference I observed may be due to influence of ocean waves. On more northerly Delaware Bay beaches, *Limulus* spawning does not take place when onshore winds create waves over ca. 30 cm (12 in) (personal observation). Waves observed on Broadkill during sampling periods were frequently over 30 cm high, and on several occasions, were ca. 50 cm (20 in) high. Whatever the cause of the low egg numbers on Broadkill Beach, the extremely low numbers indicate that it currently receives very little *Limulus* spawning.

Kelly Island, Port Mahon and Broadkill beaches varied widely from each other in their total egg numbers for the sampling season. Season egg totals (the sums of all eggs found on both transects of each study beach) were compared to the season egg totals (also the sums of all eggs found on both transects of each beach) observed on Kitts Hummock, Pickering, and North Bowers beaches, also studied during 2001, in a parallel study. Port Mahon had approximately twice as many total eggs as the next most populous beach, Kitts Hummock (248,000). In turn, Kitts Hummock and Pickering (201,000) beaches each yielded more eggs than did Kelly Island. Pickering was approximately twice as productive as Kelly Island (104,000). North Bowers had approximately half as many eggs as Kelly Island (55,000). Broadkill beach had a season total, both transects combined, of 431 eggs.

A second horseshoe crab monitoring study was completed in 2004 (Versar, 2005). The following was taken from the report of that study. Since this study was conducted, construction of the wetland restoration at Egg Island Point has been deferred due to a lack of dredged material resulting from the Deepening Project.

The Delaware Bay shoreline provides spawning habitat to horseshoe crabs, which are endemic to the Atlantic coast seaboard. From April to July, crabs that have migrated from the Atlantic continental shelf emerge along the bayshore to spawn near the high tide line of primarily sandy beaches. The peak of spawning activity usually occurs during May and June, and coincides with the highest spring tides associated with full and new moon events. At these times, female crabs, attended by several males, lay clusters of eggs up to 20-cm deep within the beach sands. The eggs develop over a minimum of two weeks and hatch into trilobite larvae, the free-swimming stage of the horseshoe crab. Because of the intensity of spawning activity throughout the spawning period and the lengthy term of development, large numbers of eggs can become dislodged from their clusters and end up exposed on the beach surface. This abundance of eggs provides critical food resources for a number of species of migratory shorebirds during a brief springtime stopover period in Delaware Bay.

After hatching, juvenile horseshoe crabs make their way into the bay where they spend the remaining spring and summer developing. For the most part, the crabs occupy shallow water inshore habitats, where they undergo several molts before heading to deeper water at the end of the warm season. Not much is known of the ecology of juvenile horseshoe crabs during this phase of growth, such as habitat preference or local movement patterns, as they are very small and difficult to sample.

The objective of this study was to evaluate horseshoe crab use of Egg Island Point, New Jersey and Kelly Island, Delaware as spawning habitat, and similarly for near shore areas, as nursery habitat for juvenile crabs. The study was conducted to provide baseline information of horseshoe crab use of the islands prior to reconstruction and to provide a means to compare post-construction conditions to gauge the effectiveness of the beneficial use of sediments. Furthermore, as the monitoring period spans the Atlantic States Marine Fisheries Commission (ASMFC) window of constraint on construction, the study was designed to identify with greater precision the critical use of the two sites by horseshoe crabs. Finally, as other species of fishes and invertebrates inhabiting nearshore habitats might be affected by the reconstruction, baseline data on these species were collected off Egg and Kelly Islands in conjunction with the juvenile horseshoe crab surveys.

During 2004, from late April to July, egg count surveys were conducted at spawning beaches on Egg Island and East Point, New Jersey and Kelly Island, Delaware. The methods used to sample horseshoe crab eggs differed somewhat between New Jersey and Delaware, and followed protocols developed independently by researchers in each state. Monitoring of horseshoe crab spawning by these researchers is ongoing and covers much of the Delaware Bay. By duplicating their respective sampling methods, it was possible to compare these egg counts with other monitoring studies and place the spawning effort observed at Egg Island and Kelly Island in to perspective with other parts of the Delaware Bay. Horseshoe crab eggs in New Jersey were sampled using methods developed by Drs. Mark Botton and Robert Loveland in Delaware Bay (primarily supported by New Jersey Sea Grant, New Jersey Department of Environmental Protection, and Public Service Electric & Gas Company). Delaware horseshoe crab egg counts followed survey protocols that have been implemented by Dr. Richard Weber of the Delaware National Estuarine Research Reserve (DNERR) (See procedure described for the 2001 horseshoe crab survey). Horseshoe crab egg samples collected from Delaware Bay beaches in New Jersey and Delaware were processed in a benthic laboratory. Sample material was washed on a 1 mm sieve to remove the formalin fixative. The material was transferred to sorting trays and inspected under a magnifying lamp. All viable horseshoe crab eggs were counted (blue-green in color) and totaled for each sample.

Juvenile horseshoe crab surveys were conducted in Delaware Bay in nearshore habitats adjacent to spawning beaches. Beaches surveyed in New Jersey and Delaware included the principal study beaches, West Egg Island, East Egg Island and Kelly Island, as well as reference beaches, East Point, Port Mahon, Kitts Hummock and North Bowers Beach. The surveys were conducted monthly from July to October during 2004. Two types of gear were used to collect juvenile crabs, a suction dredge assembly and a modified fish trawl. A survey area was delineated adjacent to each spawning beach. The survey areas were divided into 3 transect corridors, positioned parallel to shore and approximately 0.2 nautical miles (NM) in breadth. In order of proximity to shore, the corridors were defined as nearshore, midshore, and offshore habitats. Along the center of each corridor, 4 station targets were positioned at equal distances of approximately 0.2 NM apart. In total, 12 stations were defined for each beach. When sampling, the station targets were visually tracked using a Differential Global Positioning System (DGPS) during the deployment of gear. In this way, sample tows could be conducted within habitat corridors. In each of the four months of the survey period, 84 station targets were surveyed using both suction-dredge and trawl methods (7 beaches x 3 transects x 4 stations).

For suction dredging, a target station was approached while moving with the tide; when in position, the dredge was allowed to sink to the bottom. A centrifugal pump was started, and the outlet hose was monitored for sediment suspended in the discharge. As soon as the discharge was gauged acceptable, the outlet hose was directed into a catch-basin, while a 50 meter tagline was deployed over the side to standardize distance towed. At the end of the tow, the outlet hose was removed from the catch-basin, boat speed was increased to raise the dredge from the bottom, the discharge was monitored for clarity, and lastly the centrifugal pump was switched off. In this way, the suction dredge was kept from fouling. Juvenile horseshoe crabs collected by the suction dredge were sorted by hand from material within the catch-basin. Each crab was inspected for viability (many shell casts closely resembling live crabs were also collected). Most crabs passed through the dredge and pump apparatus without suffering physical damage. Up to 30 crabs were measured for prosomal width (i.e., helmet width), and any additional crabs were counted. Following sample processing, all live crabs were released overboard.

Trawl sampling was conducted using a 16-foot semi-balloon otter trawl with 1.5-inch stretch mesh in the wings and body, and 0.5-inch stretch mesh liner in the cod end. This is the same equipment used by the Delaware Division of Fish and Wildlife in their surveys for juvenile horseshoe crabs. Two-minute tows were conducted at each station. Up to 30 live horseshoe crabs, juvenile and adult, were measured for prosomal width, and released overboard. Fish collected as by-catch were identified, counted, and up to 30 were measured for total length (mm). Blue crabs collected as by-catch were measured for carapace width for up to 30 crabs, additional crabs were counted.

At the 84 stations surveyed for juvenile horseshoe crabs, samples of bottom sediment were collected during August. Sediment samples were collected using a petite-ponar benthic grab-sampler. For each station, material representing surface sediment was placed in a container labeled for station location, date, and time. Sediment samples were kept in a cooler on wet ice until they could be transferred to an analytical laboratory where they were stored in a freezer. Sediment samples were analyzed for grain size, percent silt-clay content, and total organic carbon (TOC) using ASTM Method D422-63.

The water quality parameters, salinity (ppt) and temperature (ºC), were measured during the juvenile horseshoe crab surveys for each month of sampling. Most times, surface and bottom measures of the parameters were recorded midway through suction dredge sampling at each of the seven nearshore survey areas. Water quality was not measured at West Egg Island during the August/September survey period. Bottom water quality was not measured during the October/November survey period. Salinity and temperature were measured with a pre-calibrated YSI water quality monitoring probe.

The principal objective of this study was to evaluate horseshoe crab spawning on Egg Island, New Jersey and Kelly Island, Delaware. The evaluation was based on comparing spawning intensity as measured by egg counts with other regional spawning beaches. The information from this study was necessary to provide a baseline measure of spawning prior to reconstruction, and to better define the spatial and temporal spawning characteristics along the affected beaches. A second objective was to evaluate juvenile horseshoe crab presence in nearshore habitats adjacent to the spawning beaches.

Horseshoe crab spawning at Delaware Bay beaches along the shores of Egg Island and Kelly Island followed an expected pattern during 2004. The onset of spawning in the spring was characteristically sudden and egg-laying by adult crabs was most intense during the months of May and June. Spawning of horseshoe crabs is usually synchronized with high (spring) tides associated with full or new moon phases. Survey methods for adult spawning crabs are usually scheduled around these times on the evening high tide. As our sampling schedule roughly followed 2-week intervals, we could not directly gauge the intensity of spawning, however on a number of occasions coupled adults were noted off spawning beaches, particularly at times near high tide.

Horseshoe crab spawning at Egg Island beaches was markedly different between the east and west sides of the Island. Egg counts along the west shore of Egg Island were the least productive among the New Jersey beaches. More than likely, this is in part due to the nature of the intertidal zone along this shore. In many parts, the intertidal zone leading up to the high beach is very broad and punctuated with clumps of decaying salt marsh. In effect, these might serve as obstacles to adult crabs trying to reach the higher beach to spawn. This observation is reinforced by sampling event 3 (28 May) on west Egg Island that produced high numbers of eggs. This event followed an extremely high tide that may have provided spawning adults access to this particular beach that was consistently unproductive at all other times. Spawning along the east side of Egg Island was much more prolific. Egg counts at the two beaches surveyed were comparable to those at East Point, the reference beach historically known for spawning. The east side of the island presents a more favorable habitat for spawning. The beaches have a more gradual slope and the high beach area preferred for egg-laying is much closer to the low tide mark. The spawning evaluation for Egg Island and the reference beach of East Point would benefit from a comparison with regional beaches surveyed using the same methods. At this time, comparative data are not available.

Horseshoe crab spawning at Kelly Island in Delaware was comparatively low during 2004. Egg counts from the island ranked among the lowest of 6 beaches sampled by DNERR, and several times lower than the proximal beach, Port Mahon. This last point is encouraging for the future of spawning on Kelly Island as it indicates that a fair number of crabs already spawn nearby. Spawning along the Delaware shore generally follows a consistent pattern with respect to location. For the past three years, a comparison among the 6 DNERR beaches by the total number of eggs collected has produced the same rankings. The intertidal zone at Kelly Island is interrupted in many places by a steep face of decaying salt marsh that might prevent horseshoe crabs from reaching optimal spawning beaches except during the highest tides that surmount the marsh.

Juvenile horseshoe crabs were successfully collected in nearshore habitats adjacent to New Jersey and Delaware spawning beaches. The suction dredge provided a quantitative means by which to survey the youngest of crabs. The juvenile crabs were most abundant in the nearshore habitats during July and August. This is consistent with previous descriptions of juvenile habitat preference for intertidal flats near breeding beaches. Although it is suggested that they remain there for their first and second summers, juvenile crabs from our survey appeared to be moving farther from shore and to locations further down the bay by the end of summer. The impact of the reconstruction project on juvenile horseshoe crabs is not expected to be as great as that for the eggs. Shortly after hatching and reaching the bay, crab larvae molt into the juveniles capable of motility. In that regard, they at least have the ability to disperse into extensive intertidal habitat in the Delaware Bay.

Bottom sediment characterization of nearshore habitats did not correlate with the abundance of juvenile horseshoe crabs, suggesting that the juveniles were not selecting a specific sediment type. However, a limitation of this element of our study was point sampling for sediment in the vicinity of the track towed during suction dredging which sampled crabs 25 feet to either side of the station. If the bottom habitat was more heterogeneous around the station point with respect to sediment type, this would obfuscate potential correlations. An alternative method would have been to take benthic grabs over a broader area. For example, a high count of 300 crabs was obtained in an individual tow. This reflects 6 crabs/m2 assuming 100% efficiency of the gear. By replicate sampling within these high catch areas, crab density might be better correlated to bottom sediment type.

Trawl studies also highlighted several patterns of seasonal fish usage of inshore habitats in the vicinity of the reconstruction areas. Foremost, weakfish and Atlantic croaker (drum species) are abundant during early summer and late summer, respectively. Impacts from reconstruction may also occur for these species, but are less likely given their free-swimming abilities. Blue crabs were also frequently found in the nearshore habitats but are also capable of avoidance. The information from trawl studies will provide a comparative data set for surveys conducted post construction that will better assess the beneficial use of dredged materials for reconstruction.

Due to competing time of year work restrictions for shoreline construction and dredging in Delaware Bay, it is not possible to construct the Kelly Island and Broadkill Beach projects and adhere to all recommended restrictions. For protection of over-wintering blue crab, no dredging will occur in this portion of the channel between December 1 and March 31. Construction at Kelly Island and Broadkill Beach will begin in April since April and May are acceptable dredging months. Placement of dredged material on Broadkill Beach will take three months and is scheduled from April through June. Construction activity on Kelly Island will last six months and is scheduled from April through September. As such, there would be some level of impact to spawning horseshoe crabs at both sites. This level of impact is not considered significant because the studies presented above indicate that horseshoe crab spawning at both sites is low in comparison to other monitored bay beaches. Reconstruction of the Kelly Island site will provide suitable horseshoe crab spawning habitat along its entire length, which should greatly improve the spawning productivity of the area. Monitoring can be employed during construction of Kelly Island to remove horseshoe crabs that attempt to access the work area and relocate them to a suitable spawning beach.

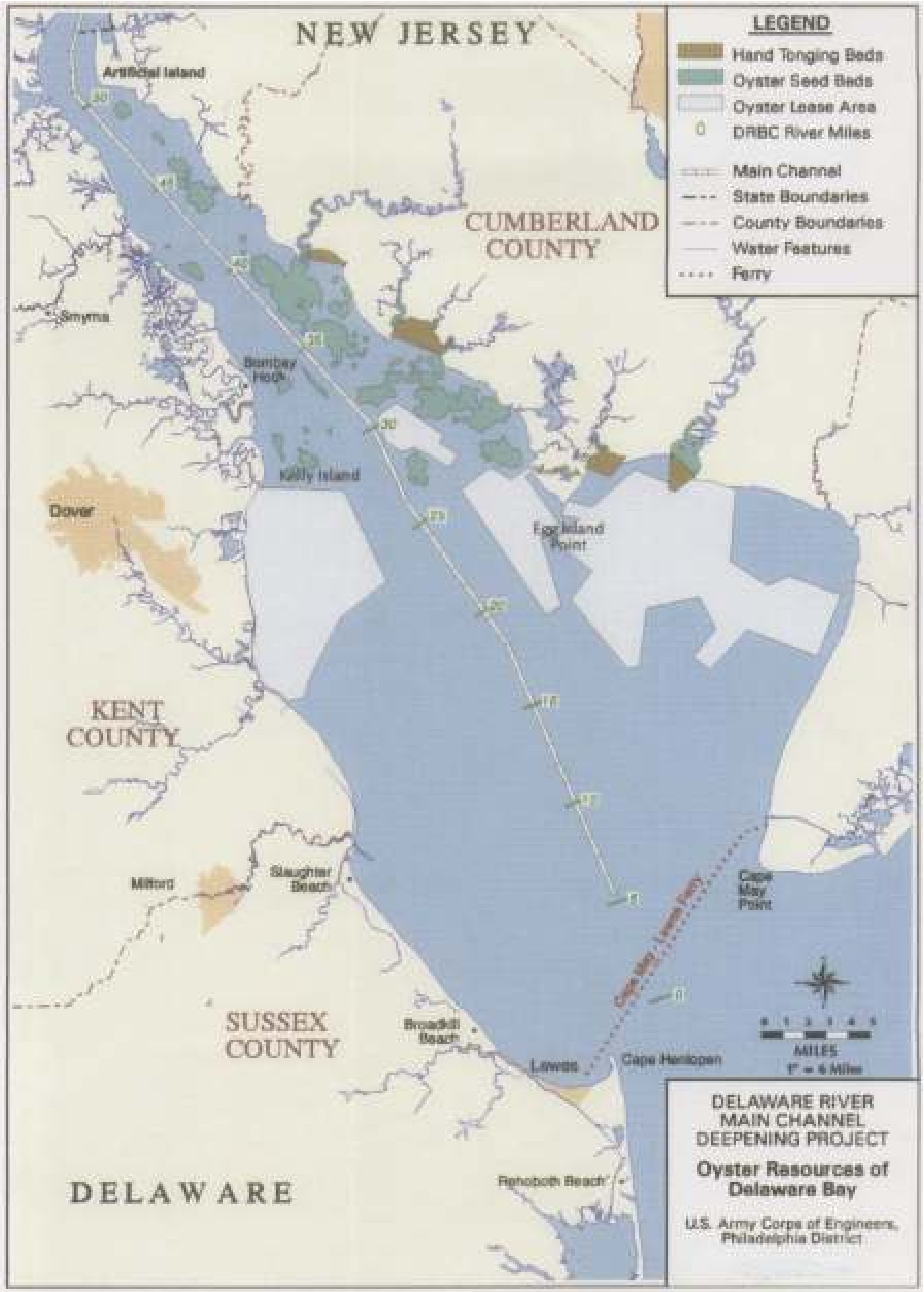
American Oyster

Oysters inhabit Delaware Bay from the mouth to Bombay Hook on the western side (Delaware) of the estuary, and to just below Artificial Island on the eastern (New Jersey) side, a distance of about 50 miles (Figure 9). Oysters have provided a sustainable food supply and contributed to the local economy of Delaware and New Jersey for centuries. From the days of the native American settlements along the shores the American (or Eastern) oyster (*Crassostrea virginica*) has been an important resource. With the coming of the European settlers, oystering increased dramatically and commercial harvesting towns and markets grew. In 1880, oyster harvesting reached its pinnacle with 2.4 million bushels.

Before the turn of the century, over 500 vessels and over 4,000 people worked in the commercial oystering industry in Cumberland County, New Jersey alone. By 1950, the harvest had dropped to around 1 million bushels. An oyster disease MSX (multinucleated sphere unknown), a protozoan parasite (*Haplosporidium nelsoni*), began to impact oyster populations by the late 1950s. Oyster harvests from planted beds dropped 90-95% while oysters in seed beds suffered a 50% mortality. Oyster harvests fell from 711,000 bushels in 1956 to 49,000 bushels in 1960. The oyster industry recovered during the 1970s and through the mid-1980s, to provide steady employment along the Delaware bayshore of both states. In 1990, a second oyster disease struck. Dermo (*Perkinus marinus*), also a protozoan parasite, invaded the oyster population that had developed a resistence to MSX, and the oyster industry nearly disappeared. Today in the Delaware Bay, Dermo disease is the overwhelming cause of adult oyster mortality. Mortality attributed to predation (mostly oyster drills, but also including crabs and dredge damage) is high in higher salinity areas (25%-50%) from Egg Island to Bennies but about 15% or less elsewhere. Recent improved estimates put an annual mortality of juvenile oysters at about 25% bay-wide, with higher estimates down-bay (HSRL, 2005).

From 1990 to 1995, the industry provided little in jobs or revenue in New Jersey. Oystering began again in 1996 under a carefully monitored direct market program. Oystering in Delaware

Figure 9 Oyster Resources of Delaware Bay



did not reopen until 2001. Recognizing the need to address the decline in the oyster resource, the New Jersey Legislature passed a joint resolution (SJR-19, 1996) establishing the "Oyster Industry Revitalization Task Force" (OIRTF) to develop recommendations that could lead to revitalization of the oyster industry and its associated economic benefits in the Delaware Bay. In 2001, representatives from both Delaware and New Jersey, including state regulatory agencies, the Delaware River and Bay Authority, the Delaware River Basin Commission, and interested citizens developed an oyster revitalization initiative based on the OIRTF. The primary goal was to enhance recruitment by enhancing natural seed supply through the planting of shell (cultch) to provide habitat for recruitment of juvenile oysters (spat). This will increase oyster habitat, expand oyster abundance, and revitalize the natural resource with concomitant improvements in Bay habitat quality from increased habitat complexity brought about by shell planting as well as increased water clarity brought about by the increased filtration by an abundant shellfish resource.

The OIRTF began addressing the oyster population problem in the Delaware estuary in 1996. It was concluded that culture practices need to be modernized to change management of the resource (DRBA, 1999). Analysis of long-term time series data suggest that enhanced abundance can stabilize natural mortality (HSRL, 2005). Recent work has shown that low abundance leads to degradation of the shell bed and eventual loss of the unique habitat of the oyster reef. Thus, a recruitment enhancement program is important for four reasons: 1) recruitment enhancement is needed to stabilize stock abundance imperiled by seven consecutive years of recruitment failure; 2) recruitment enhancement is needed to permit continuation and expansion of the oyster industry; 3) recruitment enhancement leading to increased abundance produces the shell necessary to maintain the bed; and 4) recruitment enhancement is needed to minimize the control of the oyster population dynamics by oyster disease and thereby stabilize stock abundance at a level that will permit the oyster to fulfill its keystone ecological role in the estuary as a filterer.

Since 2001, the condition of the oyster resource has deteriorated despite careful management and a limited controlled fishery, increasing the urgency for augmenting recruitment and providing habitat for oyster spat through a shell planting program. In 2006, Delaware Bay was in its seventh year of below average recruitment (less than 0.5 spat per oyster per year). Seven such consecutive years is unprecedented from the perspective of the 54-year record for which detailed survey data are available (1953-2006). Consistent recruitment failure has resulted in the decline of oyster stocks, endangering the species population dynamics, the continuance of the fishery, and the habitat quality of the oyster beds.

During the 1997-2006 period, through the efforts of the state regulatory agencies, the Shellfish Councils, and the Haskin Shellfish Research Laboratory (HSRL) of Rutgers University, a significant assessment infrastructure has been established that has produced a sustainable industry in Delaware Bay. In New Jersey, this process has been formalized through a stock assessment workshop, a rigorous stock survey, and the development of a coupled shellfisheries-disease model to permit projections of yearly harvest. Through these efforts, a consistent fishery has been established and a stable stock structure has been maintained. The resiliency of Delaware Bay oyster populations was reduced with the advent of Dermo in the 1990s. As a consequence, consecutive years of recruitment failure have significantly endangered the stock. Aside from the decline in adult oyster abundance due to high mortalities resulting from Dermo disease, there are reduced numbers of oyster spat due to relatively poor natural setting that has also contributed significantly to the demise of the Delaware Bay oyster. After two years of shell planting (and a previous small-scale test plant), results of the annual oyster stock assessment released in March 2007 indicate that throughout the New Jersey waters of Delaware Bay, the stock presents a mixture of positive and negative indicators that approximately balance. Abundance continued to be below target levels in all bay regions but above threshold levels on the medium mortality beds and Shell Rock and near, but below, threshold levels on the high mortality beds. The continued shell-planting program is anticipated to increase abundance on downbay beds in 2007. Abundance has increased each year on the high-mortality beds since reaching a post-1988 low in 2004 and abundance has moved in a positive direction for the last several years on Shell Rock. The stock continues to be disproportionately consolidated on the medium-mortality beds, a process that began in the early 2000s with persistent recruitment failure and the influence of Dermo disease downbay (Powell *et al*., 2007). However, the 2005-2006 shell planting programs have added substantially to bay-wide recruitment and these recruits are expected to underpin increases in oyster abundance in 2007, as was observed in 2006.

Turbidity generated by a hopper dredge working in the Delaware Bay channel is a concern where the channel is in close proximity to oyster beds. Oysters are broadcast spawners, meaning they release eggs and sperm into the water column. Fertilized eggs develop into planktonic (free-swimming) larvae. After a period of growth, a foot develops and the larvae settle to the bottom of the water column where they seek a hard substrate (cultch). When a suitable surface (ideally adult oyster shell) is located, the larvae cement themselves and grow to the adult form. Sediment accumulation on oyster beds reduces the ability of the bed to provide the appropriate substrate for larvae to successfully set.

Hopper dredges are self-propelled ships equipped with propulsion machinery, hoppers for dredged material storage, and dredge pumps. Dredged material is hydraulically raised through trailing dragarms in contact with the channel bottom and is discharged into the hoppers. The material is then held in the hoppers until placed at the disposal site.

Hopper dredges are often loaded past the point of overflow for economic reasons. As the hopper is filled, dredged material is stored in the hopper bins until overflow begins. The density of the hopper contents is increased by allowing the low-density supernatant to overflow back into the waterway. As the low-density supernatant overflows, the average density of the hopper contents increase. Thus, more material can be transported per trip to the disposal site or facility. This practice of overflowing hoppers to achieve a high-density load is referred to as economic loading.

In considering overflow, there is normally a tradeoff between the potential economic benefits and potential environmental effects. Overflow results in increased water column turbidity, and supernatant solids may be redeposited near the dredge site. Also, if sediments are contaminated, the overflow may result in some release of contaminants to the water column. Therefore, the relationship between dredge production, density of the hopper load, and the rate of material overflow are important variables in maximizing the efficiency of the dredging operation while minimizing contaminant release.

State environmental resource agencies have expressed concerns regarding turbidity, sedimentation of suspended solids, and potential contaminant release from hopper dredge overflow in the vicinity of oyster seedbeds in some areas near the Delaware Bay navigation channel. To address these concerns a hopper dredge overflow study was conducted (Miller et al., 2002). Currently, overflow is not permitted at any location within the Delaware River Basin and is not proposed for the Main Channel Deepening Project. But for comparison purposes, the study also evaluated non-overflow events. Turbidity plume monitoring was one element of the study.

Monitoring of the sediment plumes was accomplished using a boat-mounted 1,200-kHz Broad-Band Acoustic Doppler Current Profiler (ADCP). The instrument collects velocity vectors in the water column together with backscatter levels to determine the position and relative intensity of the sediment plume. Along with the ADCP, a MicroLite recording instrument with an Optical Backscatterance (OBS) Sensor was towed by the vessel at a depth of 15 ft. The MicroLite recorded data at 0.5-sec intervals. Navigation data for monitoring were obtained by a Starlink differential Global Positioning System (GPS). The GPS monitors the boat position from the starting and ending points along each transect.

Transects were monitored in the test area to obtain the background levels of suspended materials prior to dredging activities. A period of 8 min following the dredge passing during non-overflow dredging showed the level of suspended material to be returning to background levels. No lateral dispersion of the plume out of the channel was observed during the non-overflow dredging operation.

During overflow dredging, a wider transect was performed to determine the lateral extent of the plume. No significant change above background levels could be detected. At 1-hr elapsed time following the end of the overflow dredging operation, the levels of suspended material returned to background conditions. Again, no lateral dispersion of the plume out of the channel area was observed.

Based on these results it is concluded that non-overflow hopper dredging activities in the vicinity of oyster beds will have minimal impact regarding the rate of sediment accumulation on the beds.

Another concern relating to oysters and the deepening project is potential changes in Delaware Bay salinity patterns resulting from a 5-foot deepening. Two disease-causing organisms, *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (Dermo), and the predatory oyster drill are the primary causes of adult oyster mortality in the bay. These organisms have severely impacted the oyster population in Delaware Bay. Prevalence of these organisms declines with lower salinities. The MSX and Dermo parasites exhibit reduced virulence in the lower salinities of the upper bay, resulting in considerably lower mortality on seedbeds. This permits oysters in those areas to grow to near market size with lower losses than would occur in the down bay leased grounds. If channel deepening increases salinity in the bay, additional oyster beds could be affected by these organisms to a greater extent than the existing condition.

To address concerns related to salinity, a 3-D numerical hydrodynamic model was developed and several scenarios were selected to evaluate the impact of channel deepening on salinity patterns within the estuary (See Section 4.1.2.1 of this document). The model suggested that a negligible movement of the salt line would result from the deepening. The findings from the salinity model indicated that the predicted range of salinity changes would pose no adverse impact on oyster resources.

As part of a series of studies to characterize pre-construction conditions, the Philadelphia District conducted water quality and oyster bed monitoring in lower Delaware Bay during the 2000 and 2001 calendar years (Versar, 2001b). Water quality monitoring was conducted to provide the physical/chemical data needed to help interpret oyster population health and to provide a means to verify the hydrodynamic model predictions of potential salinity changes that may result after the channel is deepened. In consultation with the New Jersey Department of Environmental Protection, the Philadelphia District agreed to confirm and further evaluate the effects of potential salinity changes on oyster populations due to the deepening project and to implement a monitoring plan to assess any effects of the project to the oyster beds. The purpose of the 2000/2001 study was to examine the health and productivity of oyster populations on the natural seedbeds in the Delaware Bay prior to the deepening and to obtain pre-construction data on water quality. The data developed from this program will be used after the project is completed to determine if the deepening significantly impacted oyster populations in Delaware Bay.

Sandbuilder worm (*Sabellaria vulgaris*)

The sandbuilder worm or "reefworm," *Sabellaria vulgaris* is a tube-building, annelid polychaete worm common on the Mid-Atlantic coastline of the United States. This species ranges from Cape Cod to Georgia, occurring from low in the intertidal zone to shallow subtidal in waters with salinity above 15 ‰ (parts per thousand). Their life cycle includes a planktonic larval stage, and the larvae settle gregariously on a wide variety of substrata, including rocks and cobbles, clamshells, oyster bars, horseshoe crab carapaces, other worm tubes and pilings.

Sandbuilder worm tubes are built of sand grains cemented together into a hard encrustation or rock-like structure. For feeding and tube construction, the worms protrude their crown of tentacles from the tube openings. Worm tubes may be found singly or in small clusters attached to various substrata. In Delaware Bay, sandbuilder worms are also found in dense aggregations where the tubes grow in straight, parallel, spaghetti-like bundles that completely cover the substratum. These bundles may extend 20 cm or more above the substratum and be firm enough to walk on, often forming worm reef. The surface of the reef is of brown, honeycomb-like tube openings, each representing an individual sandbuilder worm. Reef development appears to be a unique characteristic of Delaware Bay populations, although masses were described on a shipwreck in North Carolina that closely resemble Delaware reefs in consistency, morphology and tidal elevation. Sandbuilder reefs form a habitat that is far more physically stable and ecologically diverse than would otherwise be found on bare rock or sand substratum. Thus, their reef structure and associated invertebrates are likely to provide food for fish and therefore represent a productive nearshore marine habitat.

For the deepening project, material dredged from the Delaware Bay channel would be placed for shoreline restoration at Broadkill Beach. This area has been known historically and recently to have sandbuilder worm reefs. Since shoreline restoration has the potential to bury and disrupt these reefs, it is necessary to determine the extent and location of present reefs as baseline data prior to construction activities. The purpose of this study was to document the presence, extent and locations of *Sabellaria vulgaris* colonies at Broadkill Beach in summer, 2001, with respect to habitat type, tidal stage, and other environmental factors.

A survey of the sandbuilder worm colonies at the Broadkill Beach sand placement site was conducted in July 20 and 21 2001 (Miller, 2002). Within an hour of the afternoon low water, the beach was walked by the contractor and his associates in two segments: on July 20, from the north end at California Avenue south to Route 16, and on July 21, from the boundary of Beach Plum Island State Park north to Route 16. These dates were chosen to be near the lowest spring tides of the month and represent the best opportunity for the colonies to be observed and measured in the intertidal and nearshore subtidal zones along this beach. The following operational definitions were used: a colony is defined as an aggregation of worm tubes, usually small in size (< 1 m across) and somewhat isolated from other worm tubes. A reef is defined as a larger structure, a meter or more across, with 5 cm or more of vertical worm tube growth.

Where sandbuilder colonies or reefs were observed, their location was determined with a handheld GPS (Garmin model GPSMAP 76) and associated with nearby streets or landmarks. The dimensions of the colony or reef, along the shore and distance seaward from the beach-slope break, were determined with a measuring tape. Various digital photographs of the whole reef, as well as close-up sections, were made to document the reef shape and structure. An on-site determination of the overall condition of the reef was made as indicated by new tube growth (tubes with a “flare” or “porch,”), tube erosion, over-settlement by mussels or tube worms, crab burrows, *et cetera*.

Reef observations and notes were recorded in the field on data sheets and additional observations were made on the study area shoreline, especially where rock, cobbles and gravel were present at the tidal level typically associated with sandbuilder reefs. At the *Sabellaria* reefs and other sites along Broadkill Beach, additional measurements were made to more fully characterize environmental conditions in the study area. These included: seawater temperature and salinity (handheld YSI model 30 meter), beach slope (inclinometer), and sediment grain size (standard dry sieving methods).

In a July, 2001 survey of Broadkill Beach, sandbuilder worm colonies were found in reef-like masses at three locations: two on the rock groins at Alabama and at Georgia Avenues, and the largest on the Old Inlet Jetty south of Route 16 and north of the Beach Plum Island boundary. At each location, sandbuilder reefs were associated with large rocks comprising the groins and jetty. No colonies were found along the beach near the beach slope break, low in the intertidal zone where they presently occur at nearby beaches in the lower Delaware Bay. In comparison with other sites studied by the contractor, sand beaches at Broadkill Beach lack the stable, cobble-sized or larger substratum to which colonies attach at nearby beaches. All colonies at Broadkill Beach are associated with large rocks on artificial structures.

Sandbuilder worms have a life cycle with a planktonic larval stage that permits broad dispersal. Larval settlement occurs over extended periods in the summer and early fall and is often gregarious. Stable substratum, for example gravel and rock of sufficient size not to be overturned by wave action, placed near mean low water should provide favorable habitat for sandbuilder worm settlement and reef development.

Sandbuilder worms are epifaunal and require water flow and wave action to provide food particles, oxygen and sand grains for tube building. While they have some capability to withstand burial under thin layers of sand, shoreline restoration would be expected to bury the present reefs at Broadkill Beach resulting in a substantial loss of this habitat. This impact could be compensated by placing suitable substratum, large rock in groins or jetties or cobble-sized gravel on sand beaches at mean low water during the summer or early fall following shoreline restoration. Other possibilities include removing current reef masses to new shoreline locations to reconstruct or reseed from enhanced larval settlement on the restored reefs.

A second study was conducted to document the presence, extent and locations of *Sabellaria vulgaris* colonies and reefs at Broadkill Beach, Kelly Island, and Port Mahon with respect to habitat type, tidal stage, and other environmental factors for both intertidal and subtidal colonies (Miller, 2004). Colonies at Slaughter Beach were surveyed as a control site, and various substrates at Broadkill and Slaughter Beaches were monitored for colonization over several months.

A survey of the intertidal sandbuilder worm colonies and reefs at Broadkill Beach, Slaughter Beach, Port Mahon and Kelly Island was conducted on the spring tides in late June and early July 2004. The basic methodology used was identical to that employed previously in the July 2001 survey of Broadkill Beach.

Following the intertidal surveys, settling plates were deployed at Broadkill and Slaughter Beaches and monitored monthly on low spring tides. These plates were replicate pairs of numbered stone pavers of slate and quartzite stone material placed on or adjacent to the reef in accessible locations. Deployment coincided with noticeable new, small *Sabellaria* tubes visible at both sites. These plates were monitored for *Sabellaria* settlement and tube growth through December 2004. Additional plates were deployed in September, October and December as needed to monitor for additional settlement. Recovered plates were photographed and measured in the field, and then either returned to their location in the field or in some cases returned to the laboratory for further analysis. In addition to photographing the natural reef on monthly site visits, additional water column and sediment measurements were made.

Sabellaria colonies and reefs were widely distributed at Broadkill Beach, Slaughter Beach and Port Mahon, but no colonies were found on the Kelly Island shoreline. This distribution is explained by the availability of stable substratum near mean low water. Favorable substrata for sandbuilder worm settlement and reef development appears to be any material of sufficient size not to be overturned by wave action. Natural substrata include gravel and rip rap rock, but colonies were also found on wood groins, horseshoe crab carapaces, and discarded tires. Smaller colonies, formed by settlement in situ or by fragmentation are present near the large reefs. While these smaller colonies were in some cases observed to have live worms and exhibit active tube growth, the longevity of these colonies is uncertain. Some colonies with low vertical relief appear susceptible to burial by natural sedimentation.

Monthly monitoring of settlement plates confirmed the suitability of two different rock substrata for settlement and tube growth, and plates deployed in late August or early September appear most favorable for tube growth in the form that results in reef formation. Tube growth rates of a centimeter or more per month were observed. Timing of available bare substratum appears to be more important than the type of material.

Construction impacts to *Sabellaria* can be compensated by either moving existing reefs to suitable areas prior to construction or by placing suitable substratum, large rocks in groins or jetties or cobble-sized gravel on sand beaches at mean low water during the late summer or early fall settlement period following shoreline restoration. Kelly Island and Broadkill Beach will be evaluated prior to construction to determine the most appropriate course of action.

Anadromous Fish Species

Anadromous defines species of fish that use freshwater rivers for spawning and marine environments for growth and migration. Spawning is triggered by increased water temperatures in spring. Anadromous species of commercial and recreational importance in the Delaware River include striped bass (*Morone saxatilis*), American shad (*Alosa sapidissima*), alewife (*Alosa pseudoharenqus*), blueback herring (*Alosa aestivalis*), and hickory shad (*Alosa mediocris*). The Delaware River Basin Fish and Wildlife Management Cooperative has recommended time of year dredging restrictions for the protection of these species. These restrictions are mostly designed to protect the spring spawning run.

Along with the Chesapeake Bay and Hudson River, the Delaware River is one of the major striped bass spawning areas along the Atlantic coast. The main spawning grounds are located between Wilmington, DE and Marcus Hook, PA. Spawning also occurs above Marcus Hook and in the Chesapeake and Delaware Canal. Striped bass support valuable commercial and recreational fisheries. Due to pollution levels in the Delaware River, the striped bass population was reduced to practically nothing in the late 20th century. During the last decade, the spawning bass population and the number of striped bass eggs, larvae, and juveniles in the Delaware River has steadily increased.

The American shad is the largest member of the herring family. Adults commonly reach four to eight pounds. Like the striped bass, the American shad population in the Delaware River has benefited from water pollution control programs. American shad spawning in the Delaware River extends from Lambertville, New Jersey upstream into the east and west branches of the Delaware River in New York. Annual shad festivals are held each spring in places like Lambertville and Easton, Pennsylvania to celebrate the return of the shad. To date there has been great variability in population estimates from year to year. Estimates in the range of 800,000 were reported in the late 1980's to mid 1990's at the Route 202 bridge in Lambertville. Recent estimates have ranged from around 100,000 to 400,000. This decrease may not reflect a decline in the environmental condition of the river. Other possible explanations are that shad are now spawning in lower portions of the river, in tributaries of the Delaware, or in other river systems. The increased striped bass population may also be impacting shad through increased predation.

River herring is a term that applies to both alewife and blueback herring. The river herring fishery is one of the oldest fisheries in North America. River herring are commercially important; they are used for human consumption, crab bait, fish meal for animal food manufacturing, and fish oil. Recreational fishing is minimal. Until the late 1960's the fishery was exclusively an inshore fishery. At that time fleets began fishing for river herring off the mid-Atlantic coast. Over the last ten years the Atlantic coast population of river herring, including the Delaware River population, has sharply declined. Contributing factors include decreased access to spawning areas from dams and other impediments, habitat degradation, over fishing, and increased predation by striped bass. In response to this decline the National Marine Fisheries Service has listed both the alewife and blueback herring as species of concern. Species of concern are defined as species which the National Marine Fisheries Service has concerns regarding status and threats, but for which insufficient information is available to indicate a need for listing under the Endangered Species Act.

Hickory shad was once thought to be a rare species in the Delaware River. Today, they are being caught in good numbers between Trenton and Lambertville by American shad anglers. Hickory shad are listed as an endangered species by both the States of New Jersey and Pennsylvania. The State of Delaware lists hickory shad as a species of conservation concern. There is a year round closed season on hickory shad in the Delaware River. Any fish caught must be released back to the river.

To protect the anadromous fish (striped bass, American shad, river herring) spawning run in the Delaware River the Delaware Basin Fish and Wildlife Cooperative recommends that dredging be restricted between the Delaware Memorial Bridge and the Betsy Ross Bridge from March 15 to

June 30 for hopper dredging and March 15 and July 31 for hydraulic dredging. These restrictions would apply to Reaches AA, A, and B of the project area. These restrictive periods will be met throughout the construction period. As such, construction of the project is not expected to adversely impact anadromous species of fish in the Delaware River.

Atlantic sturgeon

Much of the recent data on Atlantic sturgeon populations have been developed through the efforts of Dewayne Fox and Philip Simpson from the Delaware State University (Simpson and Fox 2007). Their primary research objectives have been 1) determine the status of Atlantic sturgeon populations in the Delaware River, 2) identify both the spatial and temporal extent of spawning, 3) identify critical habitats used during pre-and post-spawning movements and 4) determine duration of fresh-water residency.

Sonic tags were implanted in adult and juvenile Atlantic sturgeon captured in gill net sets and bi-catches from commercial fishing operations. Sturgeon movements were tracked using both active tag returns (boat mounted listening devices) and passive tag returns from an array of Vemco VR2 receivers mounted on navigational buoys ranging from the lower Delaware Bay to the head of tide in Trenton, New Jersey. Telemetry relocations of Atlantic sturgeon were overlaid with sediment-type data collected by Sommerfield and Madsen (2003) to determine habitat preferences. Sommerfield and Madsen utilized side scan sonar methods to produce a benthic map of the Delaware River from the region just north of Pea Patch Island upriver to approximately Bridgeport, NJ as well as the lower bay. To evaluate potential spawning locations egg mats (diameter 56-cm) were deployed in areas of the river where spawning was believed to be occurring based on active telemetry data and substrate sampling. Telemetry results indicated Atlantic sturgeon undergo a late spring/early summer upriver migration, followed by a period of dampened movement during the warm summer months of August and September, then an out migration during October and November. During the summer months juvenile Atlantic sturgeon displayed little movement compared to spring and fall months. Juvenile Atlantic sturgeon concentrated in three specific areas: Artificial Island, Cherry Island Flats, and the Marcus Hook anchorage (Figures 1 and 2). The deployed egg mats produced no sturgeon eggs but based on the gonadal biopsies of captured Atlantic sturgeon the lower limit of spawning appeared be near Tinicum Island while the upper limit is likely at the fall line near Trenton, NJ. Based on the findings of Sommerfield and Madsen (2003), Simpson and Fox postulated that the substrate composition between Marcus Hook and Tinicum Island represent suitable spawning habitat for Atlantic sturgeon.

Delaware State University's Philip Simpson and Dewayne Fox have been investigating the role of tidal flow on the migratory behavior of Atlantic Sturgeon in the Delaware Estuary. Using telemetry information they examined relationship between tidal flow and river depth on movement patterns of sonically tagged sturgeon. Out of 135 sturgeon movement tracking records, 99 resulted in a positive correlation with fish movement and tidal direction, while 14 were negatively correlated, and 22 were inconclusive. They also reported that Atlantic sturgeon do not appear to be exploiting the shallow habitats at night. These studies suggested that Atlantic sturgeons in the Delaware River were using passive tidal transport in addition to active swimming.

Surveying Atlantic sturgeon populations and their affinity to the navigational channel using traditional fisheries techniques (i.e., gill nets and trawling) is problematic due to commercial traffic, high tidal velocities, and bottom nags. Two recent studies investigated methods to document the presence of sturgeon using remote sensing techniques.

To evaluate the importance of the navigation channel as an over wintering habitat for sturgeon near Marcus Hook the USACE, Philadelphia District sponsored a remote sensing survey in the winter of 2005 (Versar, Inc. 2005b). The study employed the use of a Video Ray® Explorer submersible attached to an aluminum sled that was towed over navigational channel bottom. Images captured by the underwater camera were recorded on 60-minute Mini Digital Video Cassettes. A total of 43 hours of bottom video were collected on 14 separate survey days. Twelve days of survey work were conducted in the Marcus Hook, Eddystone, Chester, and Tinicum navigational ranges. Water clarity was sufficient to image the bottom and fish that came within 1-2 feet of the camera lens. Three unidentified sturgeon (Atlantic or Shortnose) were seen on the tapes, two in the Marcus Hook navigational Range, and one in the Tinicum navigational range. Gill net collections in the Marcus Hook anchorage during the video survey produced one Atlantic sturgeon juvenile.

Dewayne Fox from the University of Delaware investigated the feasibility of using Dual-Frequency Identification Sonar (DIDSON) and split-beam hydroacoustics to image sturgeon in hard to sample and low visibility environments. They compared split-beam and DIDSON technologies in controlled pond environments to assess the potential for conducting large-scale field surveys of Atlantic sturgeon and shortnose sturgeon in the Delaware River. In hatchery pond trials, fish sizes estimated from DIDSON images showed clear separation between the two size groups of juvenile Atlantic sturgeon. Field trials in the Delaware River suggested that although the DIDSON technology had some limitations (i.e., fish close to the bottom were difficult to image) the imaging system showed promise as a tool for determining habitat, identifying sturgeon, and estimating the abundance of sturgeon where traditional fisheries sampling cannot be conducted.

To protect Atlantic sturgeon, the Delaware Basin Fish and Wildlife Cooperative has recommended various windows for hopper dredging, cutterhead pipeline dredging, bucket dredging and blasting. All of these windows will be met during construction of the deepening project except for hopper dredging in Delaware Bay. In Delaware Bay (mouth to River mile 32) the Cooperative recommends restricting hopper dredging between 1 June and 30 November. Because of a competing restriction with over wintering blue crab it is not possible to observe this restriction. Hopper dredging will be required during the month of June for construction of the Broadkill Beach beneficial use project and during the months of June, July and August for construction of the Kelly Island beneficial use project (Figure 5). For the protection of sea turtles, a trained observer(s) is required on board any hopper dredge working below the Delaware Memorial Bridge during June through November. These observers will also be responsible for monitoring hopper dredge activity and potential impacts to Atlantic sturgeon. In addition, the monitoring program that will be employed to protect fish during the winter blasting period will also protect Atlantic sturgeon and immediately identify any problems.

Dredging provides safe passage for commercial shipping and recreational boat traffic in many river systems were sturgeon occur. Sturgeon encounters with boating traffic is common particularly in high traffic rivers like the Delaware. Ten adult Atlantic sturgeon were found in the Delaware River in 2004, six in 2005, and six in 2006 that were clearly struck by a passing ship or boat (NMFS 2007). The fish are usually 120 cm to 240 cm in length. Based on the external injuries observed, it is suspected that these strikes are from ocean going vessels and not smaller boats, although at least one fisherman reported hitting a large sturgeon with his small craft. Three carcasses of mature fish have been documented from the lower river and upper Bay during the spawning season, including two gravid mature females and one male (NOAA 1998). An eight-foot female Atlantic sturgeon was found dead on June 14, 1994, adjacent to Port Penn. A pectoral spine was used to age it at approximately 25 years old. A second female sturgeon was found in late spring/early summer of 1997 adjacent to Port Penn, just south of the eastern end of the C&D Canal. The third sturgeon, a male, was located on May 19, 1997, just north of the mouth of the Cohansey River, on Beechwood Beach. This fish appeared to have been cut in half by the propeller of a large vessel. Gonadal tissue and a pectoral spine were collected and sent to USFWS-NEFC, Fish Technology Section, Lamar, PA for analysis, which confirmed that it was a male.

Similarly, five sturgeons were reported to have been struck by commercial vessels within the James River, VA in 2005, and one strike per five years is reported for the Cape Fear River, North Carolina. Subpopulations may be affected by these incidental strikes. It is unknown what the overall impact of boat strikes is to Atlantic sturgeon subpopulations, but in small subpopulations the loss of any spawning adults could have a substantial impact on recovery. Locations that support large ports and have relatively narrow waterways seem to be more prone to ship strikes.

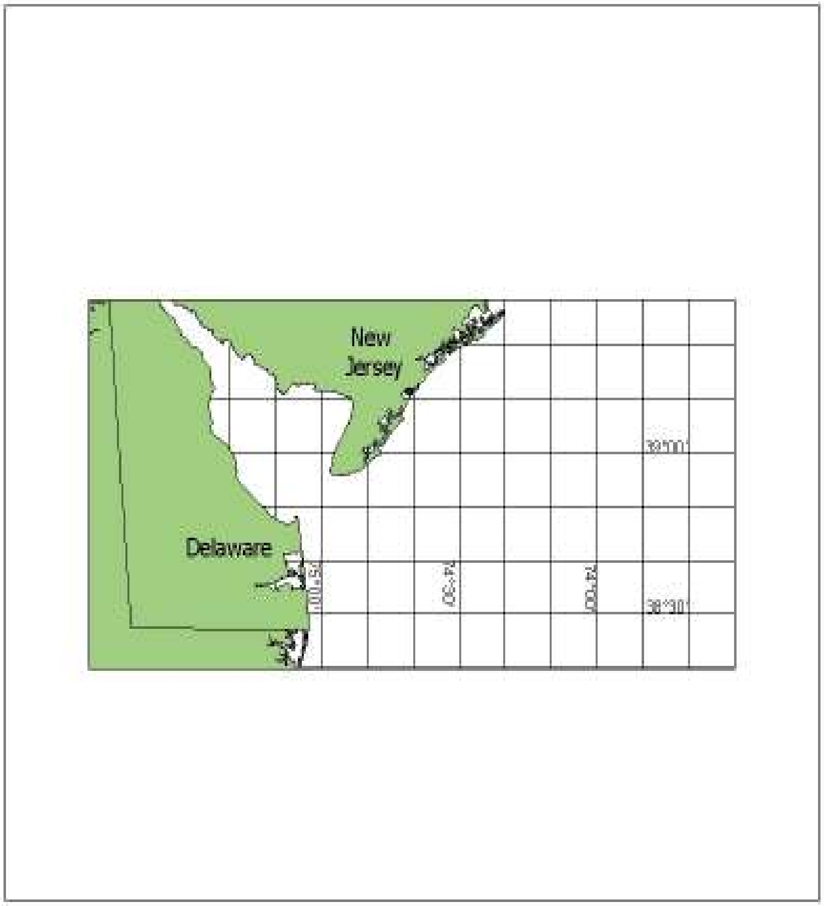
Although sturgeon mortality from encounters with commercial traffic occurs in the Delaware River, the main channel deepening project will not increase the frequency of ship strikes since an increase in the number of ships traversing the river is not anticipated. The main channel 45-foot deepening will primarily reduce the lightering of crude oil tankers in lower Delaware Bay allowing vessels to off-load more of their crude oil directly at upper river port facilities. The distance between the keel of the vessel and the deeper navigational channel bottom will essentially be the same as it is in the current 40-foot depth.

Effects on Managed Species

EFH Species Listed for the Project Area

Essential Fish Habitat within the Delaware Estuary is shown in Figure 10. Table 3 lists the 10'x10' Essential Fish Habitat squares that will be impacted by the Delaware River Main Channel Deepening project. The square reference numbers were arbitrarily assigned for reference purposes here. Channel dredging will occur in squares 1 through 5. Square 1 includes the Kelly Island wetland restoration site. Square 6 includes the Broadkill Beach site. Material dredged in squares 1 through 3 (approximately 2.5 million cubic yards) will be dredged via hopper dredge between April and August and placed at the Kelly Island site. Material dredged in squares 4 and 5 (approximately 1.6 million cubic yards) will be dredged via hopper dredge between April and June and placed at the Broadkill Beach site. Waters within squares 1 and 2 are within the mixing water salinity zone (0.5-25.0 ppt) of Delaware Bay. Waters within squares 3 through 6 are within the salt water salinity zone (>25.0 ppt) of Delaware Bay. Species with EFH designations may also utilize other mixing water salinity zone areas of the estuary that will be disturbed by channel dredging or rock blasting in the vicinity of Marcus Hook, PA.

Figure 10. Delaware Estuary Essential Fish Habitat.



Square Reference Number	Boundary Coordinates North	East	South	West
1	39° 20.0' N	75° 20.0' W	39° 10.0' N	75° 30.0' W
2	39° 20.0' N	75° 10.0' W	39° 10.0' N	75° 20.0' W
3	39° 10.0' N	75° 10.0' W	39° 00.0' N	75° 20.0' W
4	39° 10.0' N	75° 00.0' W	39° 00.0' N	75° 10.0' W
5	39° 00.0' N	75° 00.0' W	38° 50.0' N	75° 10.0' W
6	38° 50.0' N	75° 10.0' W	38° 40.0' N	75° 20.0' W

Table 3. 10'x10' Essential Fish Habitat Squares Impacted by the Delaware River Main Channel Deepening Project.

The project area contains EFH for various life stages for 26 species of managed fish. Table 4 presents the managed species and their life stage(s) that EFH is identified for the Delaware Estuary. The habitat requirements for identified EFH species and their representative life stages are provided in Table 5.

Table 4. Summary of Species with EFH Designation in the Delaware Estuary.

	Eggs	Larvae	Juveniles	Adults
Red hake (*Urophycis chuss*)	X	X	X	X
Winter flounder (*Pleuronectes americanus*)	X	X	X	X
Windowpane flounder (*Scopthalmus aquosus*)	X	X	X	X
Atlantic sea herring (*Clupea harengus*)			X	X
Bluefish (*Pomatomus saltatrix*)			X	X
Long finned squid (*Loligo pealei*)	n/a	n/a		X
Atlantic butterfish (*Peprilus tricanthus*)		X	X	X
Summer flounder (*Paralicthys dentatus*)			X	X
Scup (*Stenotomus chrysops*)	n/a	n/a	X	X
Black sea bass (*Centropristus striata*)	n/a		X	X
Spiny dogfish (*Squalus acanthias*)	n/a	n/a	X	
King mackerel (*Scomberomorus cavalla*)	X	X	X	X
Spanish mackerel (*Scomberomorus maculatus*)	X	X	X	X
Cobia (*Rachycentron canadum*)	X	X	X	X
Sand tiger shark (*Odontaspis taurus*)		X		X
Atlantic angel shark (*Squatina dumerili*)		X	X	X
Dusky shark (*Charcharinus obscurus*)		X		
Sandbar shark (*Charcharinus plumbeus*)		X	X	X
Sandbar shark (*Charcharinus plumbeus*)		HAPC	HAPC	HAPC
Atlantic sharpnose shark (*Rhizopriondon terraenovae*)				X
Scalloped hammerhead shark (*Sphyrna lewini*)			X	
Clearnose skate (*Raja eglantteria*)			X	X
Little skate (*Leucoraja erinacea*)			X	X
Winter skate (*Leucoraja ocellata*)			X	X

“n/a”: species either have no data available on designated lifestages, or those lifestages are not present in the species reproductive cycle.

The notation "X" in the table indicates that EFH has been designated within the estuary for a given species and life stage.

TABLE 5. HABITAT UTILIZATION OF IDENTIFIED EFH SPECIES AND THEIR SUMMARY OF SPECIES WITH EFH DESIGNATION IN THE DELAWARE ESTUARY

MANAGED SPECIES	EGGS	LARVAE	JUVENILES	ADULTS
Red hake *(Urophycis chuss)* (Steimle et al. 1998)	**Habitat:** Surface waters, May – Nov.	**Habitat:** Surface waters, May –Dec. Abundant in mid- and outer continental shelf of Mid-Atl. Bight. **Prey:** copepods and other microcrustaceans under floating eelgrass or algae.	**Habitat:** Pelagic at 25-30 mm and bottom at 35-40 mm. Young inhabit depressions on open seabed. Older juveniles inhabit shelter provided by shells and shell fragments. **Prey:** small benthic and pelagic crustaceans (decapod shrimp, crabs, mysids, euphasiids, and amphipods) and polychaetes).	
Winter flounder (*Pseudopleuronectes americanus)*	**Habitat:** Mud to sand or gravel;	**Habitat:** Planktonic, then	**Habitat:** Shallow water. Winter in estuaries and outer	**Habitat:** 1-30 m inshore; less than 100m offshore;

TABLE 5. HABITAT UTILIZATION OF IDENTIFIED EFH SPECIES AND THEIR SUMMARY OF SPECIES WITH EFH DESIGNATION IN THE DELAWARE ESTUARY

MANAGED SPECIES	EGGS	LARVAE	JUVENILES	ADULTS
(NOAA, 1999); Pereira et al, 1998; McClane, 1978)	from Jan to May with peak from Mar to April in 0.3 to 4.5 meters inshore; 90 meters or less on Georges Bank. 10 to 32 ppt salinity.	bottom oriented in fine sand or gravel, 1 to 4.5 m inshore. 3,2 to 30 ppt. salinity. **Prey:**nauplii, harpacticoids, calanoids, polychaetes, invertebrate eggs, phytoplankton.	continental shelf. Equally abundant on mud or sand shell. **Prey:** copepods, harpacticoids, amphipods, polychaetes	mud, sand, cobble, rocks, boulders. **Prey:** omnivorous, polychaetes and crustaceans.
Windowpane flounder *(Scopthalmus aquosus)* (Chang, 1998)	**Habitat:** Surface waters, peaks in May and October.	**Habitat:** Pelagic waters.	**Habitat:** Bottom (fine sands) 5-125m in depth, in nearshore bays and estuaries less than 75 m **Prey**: small crustaceans (mysids and decapod shrimp) polychaetes and various fish larvae	**Habitat:** Bottom (fine sands), peak spawning in May, in nearshore bays and estuaries less than 75 m **Prey**: small crustaceans (mysids and decapod shrimp) polychaetes and various fish larvae
Atlantic sea herring *(Clupea harengus)* (Reid et al., 1998)			**Habitat:** Pelagic waters and bottom, < 10 C and 15-130 m depths **Prey:** zooplankton (copepods, decapod larvae, cirriped larvae, cladocerans, and pelecypod larvae)	**Habitat:** Pelagic waters and bottom habitats; **Prey:** chaetognath, euphausiids, pteropods and copepods.
Bluefish *(Pomatomus saltatrix)*			**Habitat:** Pelagic waters of continental shelf and in Mid Atlantic estuaries from May-Oct.	**Habitat:** Pelagic waters; found in Mid Atlantic estuaries April – Oct.
Long finned squid *(Loligo pealei)*	n/a	n/a		
Atlantic butterfish *(Peprilus tricanthus)*		**Habitat**: Pelagic waters, greater than 33 ft deep	**Habitat:** Pelagic waters in 10 – 360 m	**Habitat:** Pelagic waters
Summer flounder *(Paralicthys dentatus)*		**Habitat:** Pelagic waters, nearshore at depths of 10 – 70 m from Nov. – May	**Habitat:** Demersal waters (mud and sandy substrates)	**Habitat:** Demersal waters (mud and sandy substrates). Shallow coastal areas in warm months, offshore in cold months
Scup *(Stenotomus chrysops)*	n/a	n/a	**Habitat:** Demersal waters	**Habitat:** Demersal waters offshore from Nov – April
Black sea bass *(Centropristus striata)*	n/a	**Habitat**: Pelagic and estuarine.	**Habitat:** Demersal waters over rough bottom, shellfish and eelgrass beds, man-made structures in sandy-shelly areas, *Sabellaria* reefs	**Habitat:** Demersal waters over structured habitats (natural and man-made), and sand and shell areas, *Sabellaria* reefs.
Spiny dogfish *(Squalus acanthias)*	n/a	n/a		
King mackerel *(Scomberomorus cavalla)*	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone.	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone

TABLE 5. HABITAT UTILIZATION OF IDENTIFIED EFH SPECIES AND THEIR SUMMARY OF SPECIES WITH EFH DESIGNATION IN THE DELAWARE ESTUARY				
MANAGED SPECIES	**EGGS**	**LARVAE**	**JUVENILES**	**ADULTS**
Spanish mackerel *(Scomberomorus maculatus)*	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone. Migratory	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone. Migratory	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone. Migratory	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone. Migratory
Cobia *(Rachycentron canadum)*	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone. Migratory	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone. Migratory	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone. Migratory	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone. Migratory
Sand tiger shark *(Odontaspis taurus)*		**Habitat:** Shallow coastal waters, bottom or demersal		**Habitat:** Shallow coastal waters, bottom or demersal
Atlantic angel shark *(Squatina dumerili)*		**Habitat:** Shallow coastal waters,	**Habitat:** Shallow coastal waters	**Habitat:** Shallow coastal waters, bottom (sand or mud near reefs)
Dusky shark *(Charcharinus obscurus)*		**Habitat:** Shallow coastal waters		
Sandbar shark *(Charcharinus plumbeus)* Pratt, 1999		**Habitat:** Shallow coastal waters; submerged flats (1-4 m). Important nursery area off Broadkill and Primehook beaches.	**Habitat:** Shallow coastal waters; submerged flats (1-4 m) Important nursery area off Broadkill and Primehook beaches.	**Habitat:** Shallow coastal waters; submerged flats (1-4 m)
Scalloped hammerhead shark *(Sphyrna lewini)*			**Habitat:** Shallow coastal waters	
Atl. sharpnose shark *(Rhizopriondon terraenovae)*		**Habitat:** Shallow coastal waters	**Habitat:** Shallow coastal waters	**Habitat:** Shallow coastal waters

Species by Species EFH Assessment for the Identified Species / Life Stages

Red hake (*Urophycis chuss*): The following information was taken from NOAA Technical Memorandum NMFS-NE-133 dated September 1999 (NOAA, 1999b). Delaware Bay provides EFH for eggs, larvae, juvenile and adult red hake. Red hake eggs are buoyant and are found in surface waters. Larval red hake have been collected in the upper water column of the Middle Atlantic Bight from May to December. Juvenile red hake are initially pelagic, but become demersal generally between the months of September and December. Adult red hake are demersal, but can be found in the water column. They are common on soft sediments and much less common on gravel and open sandy bottom. Juvenile and adult red hake commonly prey on small benthic and pelagic crustaceans, but also consume a variety of demersal and pelagic fish and squid. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. Eggs, larvae and juveniles are found in the water column during this time of year. Dredging activity is not likely to have a significant impact on these life stages. While adult red hake may be found at the bottom, they do not prefer sandy habitat which is predominant in the navigation channel. While some individuals could be entrained into the dredge, the level of impact is considered small. Demersal juvenile and adult red hake feed on demersal organisms. These would be removed from the channel in areas that require dredging. The loss of food source is not considered significant as red hake do not prefer sandy bottom. In addition, benthic recolonization following dredging is generally a rapid process.

Winter flounder (*Pleuronectes americanus*): Most of the material presented here is taken from the source document for winter flounder (NOAA, 1999d) and a table titled "Summary of Essential Fish Habitat (EFH) and General Habitat Parameters for Federally Managed Species" compiled by the NMFS, Northeast Regional Office, Habitat Conservation Division. The winter flounder in Delaware Bay are part of the Mid-Atlantic population that migrate inshore in the fall and early winter and spawn in late winter and early spring. In Delaware Bay, spawning takes place January, February and March, with early life stages being present in April and May (Riportella, 2001). Trawl surveys by the Delaware Department of Natural Resources and Environmental Control indicate that they are not abundant and that they occur in the lower portion of Delaware Bay where there are higher salinity levels (Michels, 2000). Generally the concern for winter flounder extends from the mouth of Delaware Bay to River Mile 35.

The eggs of winter flounder are demersal, adhesive, and stick together in clusters. They range in size from 0.74-0.85 mm in diameter. The eggs are laid when temperatures are greater than 10 degrees Celsius, in salinity levels from 10 to 30 ppt, and in depths less than 5 meters, from January through March. The habitat consists of substrates of sand, muddy sand, mud and gravel. On Georges Bank, eggs have been found in depths up to 90 meters. In New York Harbor, winter flounder used the 45 feet deep navigation channel for spawning; however, they did so in smaller numbers as compared to shallow areas adjacent to the channel (Gallo, 2000). With the exception of Georges Bank and Nantucket Shoals, winter flounder eggs are generally collected from very shallow waters (less than about 5 m), at water temperatures of 10 C or less, and salinities ranging from 10 to 30 ppt. These shallow water, nearshore habitats are of critical importance because they are most likely to be impacted by human activities. The type of substrate where eggs are found varies, having been reported as sand, muddy sand, mud and gravel, although sand seems to be the most common. Trawl surveys in Delaware Bay indicate that the winter flounder populations are smaller there than in more northern parts of their range (Michels, 2001, Scarlett 2001). Since winter flounder become less common along the New Jersey coast from north to south (Scarlett, 2001), it is therefore less likely that they would be found along the Delaware Atlantic coast.

As mentioned above, early life stage larvae are found in April and May in Delaware Bay. They occur in temperatures that are less than 15 degrees Celsius, in salinity from 4 to 30 ppt., and in depths less than 6 meters expect in Georges Bank where they have been found to depths up to 90 meters. Their preferred habitat is pelagic and bottom waters. Juveniles are generally found in water temperatures of less than 25 degrees Celsius, in salinity of from 10 to 30 ppt, and in depths from 1 to 50 meters. Their preferred habitats are substrates of mud or fine-grained sand. Their main prey species are amphipods, copepods, polychaetes, and bivalve siphons.

Adults are generally found in water temperatures of less than 25 degrees Celsius, in salinity of from 15 to 30 ppt, and in depths of from 1 to 100 meters. They prefer bottom habitats, including estuaries, with substrate of mud, sand, or gravel. Their main prey species are amphipods, polychaetes, bivalve siphons, and crustaceans. Spawning adults are generally found in water temperatures of less than 15 degrees Celsius, in salinity of from 5.5 to 36 ppt, and in depths less than 6 meters, except in Georges Bank where they spawn in depths up to 90 meters. They prefer bottom habitats, including estuaries, with substrate of mud, sand, or gravel.

Deepening the Navigation Channel has the potential to impact winter flounder if they are present; however, it is unlikely that the navigation channel has any significant use by this species.

The Deepening Project has the potential to impact eggs during the dredging of the channel and during the placement of the dredged material. It is likely that dredging will have a minimal impact on eggs of this species for the following reasons. First, there will be no dredging in lower Delaware Bay in January, February and March, which is the winter flounder spawning period. Also, most eggs have been found in shallow water, less than 5 meters. The navigation channel is presently 40 feet (12.2 meters) or greater and will be deepened to 45 feet (13.7 meters). Although eggs have been found in the 45 feet deep navigation channel of New York Harbor, the adjacent, shallow areas had greater densities, indicating that the more shallow water areas are preferred spawning habitat (Gallo, 2001). Another reason that winter flounder are likely to prefer areas adjacent to the navigation channel is that the deep draft vessels currently using the channel are creating more turbid conditions in the channel with their prop-wash that is likely to adversely impact spawning.

Since the larvae are non-dispersive, they are believed to occur in the same areas as the eggs, i.e. in shallow water. Because of the reasons listed above for eggs, it is unlikely that the navigation channel would provide preferred habitat for larvae.

Any juveniles or adults that use the channel could be adversely impacted by dredging, either by entrainment or increased turbidity. However, because of the channel's use by deep draft vessels and the resulting turbidity and prop wash, it is unlikely that the navigation channel has significant use from these life stages of winter flounder.

The placement of dredged material along the shallow shoreline of Delaware at the Kelly Island wetland restoration and the beach restoration at Broadkill Beach are more likely to have adverse impacts on spawning adults and early life stages (larvae and juveniles) than channel dredging. However, the impacts are not expected to be significant for the following reasons. First, as stated above, there would be no dredging during the winter flounder spawning period. Also, data from New Jersey and Delaware indicate that winter flounder populations currently using Delaware Bay are smaller than those further north in the range and become less abundant moving from northern New Jersey to southern New Jersey. In addition, the wetland restoration at Kelly Island will create tidal guts in the wetlands with abundant invertebrate fauna that will be beneficial to early life stages of winter flounder that will compensate for any temporary, minimal impacts that would occur from construction of the wetland restoration (Goodger, 2001). At Broadkill Beach, material will be contained on the beach until after September 15 for the protection of sandbar shark. This will also provide protection to eggs and early life stages of winter flounder within the project area. It is also noted that construction is a onetime event except for occasional maintenance that can be done outside the winter flounder window.

Windowpane flounder (*Scopthalmus aquosus*): The following information was taken from NOAA Technical Memorandum NMFS-NE-137 dated September 1999 (NOAA, 1999c). Delaware Bay provides EFH for eggs, larvae, juvenile and adult windowpane flounder. In Delaware Bay juveniles and adults are considered abundant in the mixing water and seawater zones. Windowpane is a year round resident off southern New Jersey and occurs primarily on sand substrates. Juvenile and adult windowpane feed on small crustaceans and various fish larvae. Eggs and larvae are pelagic and should not be impacted by dredging activities. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. Juvenile and adult windowpane flounder would be present during this time period. Some individuals may be entrained into the dredge. This is more likely for smaller juveniles, as older juveniles and adults would be expected to move out of the way. There would be some loss of shallow water habitat at the Broadkill Beach and Kelly Island sites.

Atlantic herring (*Clupea harengus*): The following information was taken from NOAA Technical Memorandum NMFS-NE-192 dated July 2005 (NOAA, 2005a). Delaware Bay provides EFH for juvenile and adult Atlantic herring. They are pelagic and form large schools, feeding on planktonic organisms. Spawning occurs in the spring, summer and fall from Labrador to Nantucket shoals. In Delaware Bay, juveniles are considered common in both the seawater and mixing water zones. Juveniles are common in April and May, rare from June to October, and not present November to March. Adult Atlantic herring are considered common in the seawater zone and rare in the mixing water zone. Adults are common in November to January and rare the remainder of the year. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. Impacts to adult Atlantic herring would be minimal because they are rare in Delaware Bay during this portion of the year. Juveniles are common in April and May, while some individuals could be entrained into the dredge, the level of impact is considered small. Atlantic herring feed on planktonic organisms, which will not be affected by dredging activity.

Bluefish (*Pomatomus saltatrix*): The following information was taken from NOAA Technical Memorandum NMFS-NE-198 dated July 2006 (NOAA, 2006). Delaware Bay provides EFH for juvenile and adult bluefish. Bluefish eggs and larvae are pelagic and are considered rare in Delaware Bay. Juveniles are considered abundant in Delaware Bay; they move to estuarine habitats in the Middle Atlantic Bight in late May to mid-June. Adults are less concentrated along the Mid-Atlantic coast, occurring mostly along Long Island, offshore south of Cape Cod, and on Georges Bank. Juveniles occur in many habitats, but do not use the marsh surface. Adult bluefish occur in the open ocean, large embayments, and most estuarine systems within their range. Studies suggest that juvenile and adult bluefish feed on whatever taxa are locally abundant, including fish, crustaceans and polychaetes. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. Juvenile and adult bluefish would be present during this time period. Some individuals may be entrained into the dredge. This is more likely for young-of-year juveniles, as older juveniles and adults would be expected to move out of the way. Benthic invertebrates would be removed from the channel in areas that require dredging. Benthic recolonization following dredging is generally a rapid process. Overall, no more than minimal impact on bluefish is anticipated as a result of the project.

Long finned squid (*Loligo pealei*): The following information was taken from NOAA Technical Memorandum NMFS-NE-193 dated August 2005 (NOAA, 2005b). Delaware Bay provides EFH for adult long finned squid. Adult longfin squid inhabit the continental shelf and upper continental slope to depths of 400 meters. In summer and fall they inhabit inshore waters as shallow as 6 meters. They are found on mud or sand/mud substrate. They travel in schools and feed on planktonic organisms, crustaceans and small fish. In the Hudson-Raritan estuary, adults have mostly been collected at depths of 15-18 meters (50-60 feet) at salinities of 20-33 ppt. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. Adult long finned squid could be present during this time period. Some individuals may be entrained into the dredge. No impact on their habitat or food source is anticipated. Overall, no more than minimal impact on long finned squid is anticipated as a result of the project.

Atlantic butterfish (*Peprilus triacanthus*): The following information was taken from NOAA Technical Memorandum NMFS-NE-145 dated September 1999 (NOAA, 1999e). Delaware Bay provides EFH for larvae, juvenile and adult Atlantic butterfish. Juvenile and adult butterfish are pelagic fishes that form loose schools, often near the surface. Butterfish feed mainly on planktonic organisms. Butterfish eggs and larvae are pelagic and occur from the outer continental shelf to the seawater zone of estuaries in the Middle Atlantic Bight. In Delaware Bay, eggs are considered rare in the seawater zone and larvae are common. Eggs and larvae are present in May, June and July. Juvenile butterfish are common in both the mixing water and seawater zones. Spawning adults are rare and adults are rare in the mixing water zone and common in the seawater zone. Juveniles are present from July to December; adults are present May to October. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. While larvae, juveniles and adults are likely to be present during dredging, the potential impact is considered small because of their pelagic nature. Atlantic butterfish feed on planktonic organisms, which will not be affected by dredging activity.

Summer flounder (*Paralichthys dentatus*): The following information was taken from NOAA Technical Memorandum NMFS-NE-151 dated September 1999 (NOAA, 1999g). Delaware Bay provides EFH for juvenile and adult summer flounder. Summer flounder spawn during fall and winter in open ocean areas of the continental shelf. Spawning occurs while the fish are moving offshore to their wintering grounds. Adult summer flounder normally inhabit shallow coastal and estuarine waters during the warmer months of the year and remain offshore during the colder months. Juveniles are distributed inshore and in estuaries during spring, summer and fall. Some juveniles move offshore during the colder months, but many remain inshore. Juvenile and adult summer flounder are reported as preferring sandy habitats. Summer flounder are opportunistic feeders. Smaller flounder focus on crustaceans and polychaetes while fish become more important in the diets of larger juveniles. Adult summer flounder feed on fish and crustaceans. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. Juvenile and adult summer flounder would be present during this time period. Some individuals may be entrained into the dredge. This is more likely for young-of-year juveniles, as older juveniles and adults would be expected to move out of the way. There would be some loss of shallow water habitat at the Broadkill Beach and Kelly Island sites. The creation of tidal guts at the Kelly Island wetland restoration site will provide habitat. Benthic invertebrates would be removed from the channel in areas that require dredging. Benthic recolonization following dredging is generally a rapid process.

Scup (*Stenotomus chrysops*): The following information was taken from NOAA Technical Memorandum NMFS-NE-149 dated September 1999 (NOAA, 1999f). Delaware Bay provides EFH for juvenile and adult scup. The life history of scup is typical of most demersal fishes, with pelagic eggs and larvae, and a gradual transition to a demersal adult stage. Spawning occurs from May to August, and larvae begin to become demersal in early July. During the summer and early fall juveniles and adults are common in most large estuaries in open and structured habitats where they feed on a variety of benthic invertebrates. As a temperate species, scup is at the northern limits of its range in the northeastern United States and migrates south in the winter to warmer waters south of New Jersey. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. Eggs and larvae are found in the water column during this time of year. Dredging activity is not likely to have a significant impact on life stages within the water column. Larvae, juvenile and adult scup can be found near the bottom in a variety of habitats during the summer. Some individuals may be entrained into the dredge. This is more likely for larvae and juveniles as adults would be expected to move out of the way. Benthic invertebrates would be removed from the channel in areas that require dredging. Benthic recolonization following dredging is generally a rapid process. Overall, no more than minimal impact on scup is anticipated as a result of the project.

Black sea bass (*Centropristis striata*): The following information was taken from NOAA Technical Memorandum NMFS-NE-200 dated February 2007 (NOAA, 2007a). Delaware Bay provides EFH for juvenile and adult black sea bass. Primary spawning habitats for black sea bass appear to be located in the nearshore continental shelf. Larvae have not been reported in Delaware Bay. Juveniles and adults can be found in Delaware Bay during the spring, summer and fall. In the winter they occur mostly offshore on the shelf. Black sea bass are generally associated with structurally complex habitats. They use a variety of man-made habitats including artificial reefs, shipwrecks, bridge abutments, piers, pilings, groins, submerged pipes and culverts, navigation aids, anchorages, rip rap barriers, fish and lobster traps, and rough bottom along the sides of navigation channels. Juvenile and adult black sea bass feed on benthic and epibenthic crustaceans, fish and squid. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. Juvenile and adult black sea bass would be present during this time period. Some individuals may be entrained into the dredge. This is more likely for young-of-year juveniles, as older juveniles and adults would be expected to move out of the way. There would be some loss of habitat at the Broadkill Beach site if existing groins are covered with sand. Sabellaria reefs also provide habitat which would be lost if covered by sand. Construction impacts to *Sabellaria* can be compensated by either moving existing reefs to suitable areas prior to construction or by placing suitable substratum, large rocks in groins or jetties or cobble-sized gravel on sand beaches at mean low water during the late summer or early fall settlement period following shoreline restoration. Kelly Island and Broadkill Beach will be evaluated prior to construction to determine the most appropriate course of action. Benthic invertebrates would be removed from the channel in areas that require dredging. Benthic recolonization following dredging is generally a rapid process.

Spiny dogfish (*Squalus acanthias*): The following information was taken from NOAA Technical Memorandum NMFS-NE-203 dated December 2007 (NOAA, 2007b). Spiny dogfish are the most abundant shark in the north Atlantic. They travel in groups and are highly migratory. They are most abundant from Nova Scotia to Cape Hatteras, North Carolina. Delaware Bay provides EFH for juvenile spiny dogfish. Spiny dogfish have been reported from many east coast estuaries. They enter estuaries in summer and fall, but only in outer portions where the water is cooler and more saline. Spiny dogfish feed on fish squid and ctenophores. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. Juvenile spiny dogfish could be present during this time period. Some individuals may be entrained into the dredge. This is more likely for smaller juveniles, as older juveniles would be expected to move out of the way. Overall, no more than minimal impact on spiny dogfish is anticipated as a result of the project.

Spanish (*Scomberomorous maculatus*) and King (*S. cavalla*) mackerel: Delaware Bay provides EFH for eggs, larvae, juvenile and adult Spanish and king mackerel. Spanish and king mackerel are schooling species that inhabit coastal waters of the Western Atlantic Ocean and Gulf of Mexico and associated estuaries. On the Atlantic coast, these species are most abundant from Chesapeake Bay to southern Florida. The migration patterns of Spanish and king mackerel fluctuate with climate variation and changes in water temperature. Preferred water temperatures for these species are greater than 64 ° F for Spanish and greater than 68 ° F for king mackerel. Both species favor shallow, coastal ocean waters, but freely enter coastal estuaries like Chesapeake Bay in warmer months, with visits generally confined to the middle and lower Bay from spring to autumn. These species are only occasionally found in the upper Bay. Spanish mackerel spawn over a wide area of the mid- to outer-continental shelf, including that region of the Atlantic coast associated with the Chesapeake Bay. Spawning off the coast of Virginia occurs from late spring through late summer. Although mackerel are not a predominant commercial or recreational fishery in Chesapeake Bay, they rely upon coastal waters of the region for spawning and larval stages may use the Bay as nursery grounds. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. Eggs and larvae are planktonic so minimal impact is anticipated as a result of dredging. Spanish and king mackerel juveniles and adults could be present during this time period. Some individuals may be entrained into the dredge. This is more likely for smaller juveniles, as older juveniles and adults would be expected to move out of the way. Benthic invertebrates would be removed from the channel in areas that require dredging. Benthic recolonization following dredging is generally a rapid process.

Cobia (*Rachycentron canadum*): Delaware Bay provides EFH for eggs, larvae, juvenile and adult cobia. In the Atlantic, cobia is found from Massachusetts to the Florida Keys and in the Gulf of Mexico. Cobia migrate north in the spring from their wintering grounds in the Florida Keys. They occur in pelagic waters around sandy shoals or capes and offshore bars, high profile rocky bottoms and the Oceanside of barrier islands. Cobia can also be found in high salinity estuaries. Cobia spawn from late June to mid-August along the south eastern United States. Cobia eggs are pelagic. They feed on some fishes, although the bulk of their diet is crustaceans and other invertebrates. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. Eggs and larvae are planktonic so minimal impact is anticipated as a result of dredging. Cobia juveniles and adults could be present during this time period. Some individuals may be entrained into the dredge. This is more likely for smaller juveniles, as older juveniles and adults would be expected to move out of the way. Benthic invertebrates would be removed from the channel in areas that require dredging. Benthic recolonization following dredging is generally a rapid process.

Sandbar shark (*Charcharinus plumbeus*): The sandbar shark (*Carcharhinus plumbeus*) inhabits coastal waters of the Atlantic from Massachusetts to southern Brazil. The sandbar shark is an important component of shark fisheries, and it has been severely overfished in the north Atlantic. A management plan for the sandbar shark, involving catch quotas and size restrictions, was implemented in U.S. waters in 1993. Since that time the north Atlantic population has ceased declining and is beginning to show signs of recovery. The Delaware Deepening Project contains areas designated as “Habitat Areas of Particular Concern” (HAPC) for the sandbar shark. HAPC are areas of Essential Fish Habitat (EFH) that are judged to be particularly important to the long-term productivity of populations of one or more managed species, or to be particularly vulnerable to degradation (NOAA, 1999a).

Sandbar sharks use the shallows of Delaware Bay as an important seasonal nursery ground. The juvenile sharks (1 to 6 yr. old) return to the Bay from wintering grounds in the Carolinas, in mid May. Adult females visit the Bay to pup (deliver live-born young) in the first weeks of June. This has not been directly observed yet, many young caught in June bear fresh umbilical cord remnants and all have open umbilical scars indicating very recent birth. Newborns weigh about 1.5 pounds and are about 1.5 feet in length. Tag returns show that they stay in the bay feeding throughout the summer and depart for their winter (secondary) nurseries when the waters turn cool in mid October. Most newborns are found on the shallow flats in the Southwestern Bay although they seem to radiate out and use more of the Bay during the summer, as they get larger. Telemetry studies show that juveniles cross the bay mainly on the bottom. They are bottom feeders, preying on fish, particularly flat fish, crabs (blue crabs and spider crabs) and other benthic organisms. The sharks' main nursery areas on the East Coast are in Delaware and Chesapeake bays. They formerly used Great South Bay, Long Island, N. Y. but surveys show that they have not used it recently, possibly due to anthropogenic or geological (morphological) changes (Pratt, 1999).

Pup and juvenile sharks use submerged flats for residence and feeding in water depths of from 1 to 4 meters. On the Delaware coast they extend from Roosevelt Inlet at the southern terminus of Broadkill Beach, to Port Mahon in the north. The greatest concentrations of young sharks occur off Broadkill and Primehook beaches, Delaware. They also are found in great numbers on submerged flats off the New Jersey shore (1-4 m) between Villas and Reed's Beach and shoal areas throughout the Bay such as Deadman and Hawksnest Shoal. They are limited by salinity to areas south of the latitude of Fortescue, NJ. Juveniles and pups may be caught almost anywhere in the bay, but the southwest coastal areas have the greatest consistent numbers as reflected in Catch per Unit Effort (CPUE) data (Pratt, 1999).

The habitat along the lower Delaware Bay coast in Delaware has been designated as "Habitat Areas of Particular Concern" by the NMFS. Pratt (1999) believes that there will be a great potential to impact shark pups rend their food source of benthic organisms in the nursery areas along the Delaware Bay Coast, especially offshore from Broadkill Beach to Slaughter Beach, if sand is deposited near the beach (in areas 1 – 4 m deep) in the nursery season. Potential impacts may include but not be limited to: changing the habitat characteristics, depth, profile, odor, turbidity and fauna of the area. Loss of forage would also occur. Prey species, principally crabs and fish of many species, may be disrupted directly by the presence of physical activity in the area and indirectly by the covering of vulnerable food web organisms with sand. A "closed" window from 1 May to 15 September was recommended by the National Marine Fisheries Service (Gorski, 2000) to prevent potential impacts to newborn and juvenile sharks such as suffocation. After this time period, the young sharks have reached a larger size where they would be more able to avoid the sand placement operations.

On 7 November 2000 representatives from the Corps and the NMFS held a teleconference to explore methods to place sand on Broadkill Beach during the Spring/Summer without significantly impacting the sandbar sharks puping (females giving birth to live-born young) and the nursery area that is located offshore in shallow waters. It was agreed that sand placement can be performed during the period from 1 May to 15 September using the following conservation measures:

A sand dike, 200 to 300 feet in length, will be constructed above mean high water (MHW) to contain dredged material that is pumped landward of it. The dike will be constructed using existing sand on the beach. The dike will be long enough that most dredged material will drop out on the beach and not return to the bay. As material is deposited the dike may be repositioned seaward to contain the required tilling above MHW for that section of beach. The slurry will still be controlled by the dike along the shoreline. No dredged material will be hydraulically placed below MHW during the restricted period. The dike will be extended down the beach as the area behind the dike is tilled and the dredged pipe is lengthened. The dredged material that has been deposited will be built into dunes. It is expected that little of this material will be re-deposited by wave action during the spring/summer window period since weather is generally mild, except for possible hurricanes. After September 15, some dredged material will be graded into the bay to widen the beach.

The dredge pipe will be placed on pontoons for a minimum of 1000 feet, beginning at approximately elevation -4.7 NGVD, extending offshore to avoid disrupting along shore traveling by the young sandbar sharks. This distance will be determined by the National Marine Fisheries Service. The remainder of the pipeline extending to the beach, and back to the dredge, can rest on the bottom.

Sand tiger shark (*Odontaspis taurus*): The New Jersey Department of Environmental Protection considers the sand tiger shark to be abundant in New Jersey waters. Delaware Bay provides EFH for neonates and adult sand tiger shark. In the North Atlantic, the sand tiger shark ranges from the Gulf of Maine to Florida and into the Gulf of Mexico. The sand tiger shark is often found in sandy coastal waters, shallow bays, estuaries and rocky or tropical reefs. They are often seen trolling the ocean floor in the surf zone, very close to shore. Although most often found in shallow waters they also swim down to depths of 200 meters. Newborns are approximately 3 feet in length, and are usually born in the winter. The sand tiger shark eats mainly bony fish such as herring, snappers, eels, mackerels, rays, squid, crustaceans and occasionally small sharks. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. Newborns should not be present during this time. Adults could be present, but it is unlikely that they would be impacted by construction activities. Adults are highly mobile and are capable of avoiding impact areas. Benthic invertebrates would be removed from the channel in areas that require dredging. Benthic recolonization following dredging is generally a rapid process.

Atlantic angel shark (*Squatina dumerili*): Delaware Bay provides EFH for larvae, juvenile and adult Atlantic angel shark. This shark is a bottom dwelling, flat, skate like shark. Neonates/early juveniles, juveniles and adults are found in shallow coastal waters off of southern New Jersey, Delaware and Maryland, including the mouth of Delaware Bay. Little is known about this species. It is found seasonally in shallower water. Off the eastern United States it appears to move inshore in the spring and summer, and disappears, apparently into deeper water in other seasons. Diet includes small bottom fishes (flounders, skates and other bottom fishes), crustaceans and bivalves. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. Newborns juveniles and adults could be present during this time period. Some individuals may be entrained into the dredge. This is more likely for newborns and smaller juveniles, as older juveniles and adults would be expected to move out of the way. Benthic invertebrates would be removed from the channel in areas that require dredging. Benthic recolonization following dredging is generally a rapid process.

Dusky shark (*Charcharinus obscurus*): Delaware Bay provides EFH for young dusky shark. Adults tend to avoid areas of low salinity and rarely enter estuaries. The young congregate in shallow coastal water in estuaries and bays from New Jersey to Cape Hattaras, North Carolina. Duskies migrate northward in summer as waters warm and retreat southward in fall as water temperatures drop. The dusky shark is a live bearer; young are born at approximately 3 feet in length. Their diet includes bony fishes, cartilaginous fishes and squid. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. Young could be present during this time period. Considering the size of newborns (3 feet) they may be mobile enough to avoid a dredge or disturbance at the placement sites.

Atlantic sharpnose shark (*Rhizopriondon terraenovae*): Delaware Bay provides EFH for adult Atlantic sharpnose shark. The Atlantic sharpnose shark is common in coastal waters at depths of 12 meters (42 feet) or less during the summer months. It often occurs close to the surf zone off sandy beaches, and also enclosed bays, sounds, and harbors, in estuaries and river mouths.

During the winter this shark can be found at depths greater than 27 meters (90 feet). This shark is commonly found in coastal waters of South Carolina, Florida and the Gulf of Mexico where it is a year round resident. The New Jersey Department of Environmental Protection considers this species rare in New Jersey waters. Diet includes shrimp, molluscs and small fishes. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. Adults could be present during this time period. Adults are highly mobile and capable of avoiding impact areas. Benthic invertebrates would be removed from the channel in areas that require dredging. Benthic recolonization following dredging is generally a rapid process.

Scalloped hammerhead shark (*Sphyrna lewini*): Delaware Bay provides EFH for juvenile scalloped hammerhead sharks. The New Jersey Department of Environmental Protection considers this species rare in New Jersey waters. The scalloped hammerhead is a coastal pelagic species, it occurs over continental and insular shelves and in nearby deeper water. It is found in warm temperate and tropical waters. This shark feeds primarily on fish and occasionally on squid and octopus. Juveniles could be present in lower Delaware Bay during the time of dredging. Some individuals may be entrained into the dredge. This is more likely for smaller juveniles, as older juveniles would be expected to move out of the way.

Clearnose skate (*Raja eglantteria*): EFH is designated within the project area grid for clearnose skate juveniles and adults. They are broadly distributed along the eastern United States from Nova Scotia to Northeastern Florida. Juveniles and adults are most abundant in the summer months and less abundant in the cooler months of fall, winter and spring. Clearnose skate prefer soft bottom habitats but can also be found in rocky or gravelly bottoms. According to the 1966-1999 Delaware Division of Fish and Wildlife bottom trawl surveys, juveniles and adults mostly occur in depths of 8-14 meters during the fall. The diet of the clearnose skate consists of polychaetes, amphipods, mysid shrimp, crab, squid, bivalves and small fish. Although dredging may affect feeding success, this will be a temporary occurrence in a relatively small area. Turbidity may impact sight feeding, but the present population will undoubtedly flee to neighboring waters where feeding will be less problematic. Benthic invertebrates would be removed from the channel in areas that require dredging. Benthic recolonization following dredging is generally a rapid process. Although this EFH may encompass part of the project area, the clearnose skate is broadly distributed along the eastern United States and the habitat will rapidly recover. No more than minimal impact on all life stages of the clearnose skate EFH is anticipated as a result of the proposed project.

Little skate (*Leucoraja erinacea*): EFH is designated within the project area grid for little skate juveniles and adults. They are broadly distributed from Nova Scotia to Cape Hatteras. Juveniles and adults mostly prefer sand or gravelly bottoms but some mud also. Little skate occur in Delaware Bay when temperatures are less than 15 °C (Late October through May). Few are caught during the summer months as most move to deeper waters. The most important prey items to little skate are decapod crustaceans, amphipods and polychaetes. Dredging in the Delaware Bay channel is scheduled to occur during the months of April through August. Juvenile and adult little skate would be present during April and May. Some individuals may be entrained into the dredge. This is more likely for young-of-year juveniles, as older juveniles and adults would be expected to move out of the way. Although dredging may affect feeding success, this will be a temporary occurrence in a relatively small area. Turbidity may impact sight feeding, but the present population will undoubtedly flee to neighboring waters where feeding will be less problematic. Benthic invertebrates would be removed from the channel in areas that require dredging. Benthic recolonization following dredging is generally a rapid process. No more than minimal impact to feeding success should occur to little skate.

Winter Skate (*Leucoraja ocellata*): EFH is designated within the project area grid for winter skate juveniles and adults. They are broadly distributed from Newfoundland to Cape Hatteras. Juveniles mostly prefer sand, gravel bottoms and some mud substrate. Winter skate generally feed on polychaetes, amphipods, decapods, isopods, bivalves, squid, crab and fishes. Polychaetes and amphipods are the predominant prey. Although dredging activities may affect feeding success, this will be a temporary occurrence in a relatively small area. Additionally the wide range of prey increases the potential for feeding success. Benthic invertebrates would be removed from the channel in areas that require dredging. Benthic recolonization following dredging is generally a rapid process. No more than minimal impact to feeding success should occur to winter skate.

E. EFFECTS ON ENDANGERED SPECIES

Sea turtles

The Philadelphia District is concerned with the possible negative impacts that dredging may exert on threatened and endangered populations of sea turtles in the Delaware Estuary. They also recognize the need to monitor activities which may present a genuine threat to species of concern. It is the intention of the Philadelphia District to continue monitoring for sea turtles during dredging projects, when warranted. Sea turtle observer(s) shall be on board any hopper dredge working in areas of concern (below the Delaware Memorial Bridge) during June through November. The observer shall be on board the dredge continually during this window. While on board the dredge the observer shall provide the required inspection coverage on a rotating, six/eight hours on and six/eight hours off, basis. In addition, these rotating six/eight hour periods should vary from week to week. All such dredging and monitoring will be conducted in a manner consistent with the Incidental Take Statement issued by NMFS for this project. The District will continue to coordinate monitoring results with NMFS, and work to develop appropriate measures to minimize impacts.

Whales

Due to the slow nature of whales it is the District's intention to slow down to 3 - 5 mph operating speed after sun set or when visibility is low when a whale is known to be in the project area. Contract plans and specifications will require the hopper dredge operator to monitor and record the presence of any whale within the project vicinity.

Shortnose sturgeon

There may be a potential impact to overwintering juvenile shortnose sturgeon because rock blasting will be required to remove bedrock in the Marcus Hook range performed between 1 December and 15 March. The measures listed below focus on preventing physical injury to juveniles that may be near the blasting area, but would likely protect the larger adult fish if any were present since there is evidence that smaller fish are more vulnerable to injury than larger fish (Philadelphia District, 1997). Studies have shown that the size of charge and distance from detonation are the two most important factors in determining fish mortality from blasting (Teleki and Chamberlain 1978, Wiley et al. 1981, and Burton 1994). In addition, the measures listed below were used in North Carolina to successfully minimize impacts to shortnose sturgeon and have been coordinated with the NMFS for use with this project:

- Before each blast, four (4) sinking gillnets (5.5 inch mesh, 100 meters long) will be set to surround the blast area as near as feasible. These nets will be in place for at least 3 hours and none of the nets will be removed any sooner than 1 hour before the blast. This may require overnight sets. Any sturgeon removed (shortnose or Atlantic) will be released at a location approved by the National Marine Fisheries Service.

- Channel otter trawl nets will be set downcurrent of the blast area within 10 minutes of blast discharge in order to capture and document dead or injured fish.

- Scare charges will be used for each blast. A scare charge is a small charge of explosives detonated immediately prior to a blast for the purpose of scaring aquatic organisms away from the location of an impending blast. Two scare charges will be used for each blast. The detonation of the first scare charge will be at 45 seconds prior to the blast, with the second scare charge detonated 30 seconds prior to the blast. Some marine mammals and fish may not locate the origin of the first scare charge. The second scare charge allows these creatures to better locate the source of the charge and maneuver away from the source.

- Blast pressures will be monitored and upper limits will be imposed on each series of 5 blasts.

- Average pressure shall not exceed 70 pounds per square inch (psi) at a distance of 140 feet.

- Maximum peak pressure shall not exceed 120 psi at a distance of 140 feet.

- Pressure will be monitored for each blast only at a distance of 140 feet.

- Surveillance for schools of fish will be conducted by vessels with sonar fish finders for a period of 20 minutes before each blast, and if fish schools are detected, blasting will be delayed until they leave. The surveillance zone will be approximately circular with a radius of about 500 feet extending outward from each blast set.

Adverse impacts to fish will be further minimized by conducting blasting between December 1 and March 15 as recommended by the Delaware River Basin Fish and Wildlife Management Cooperative, and using controlled blasting methods such as delayed blasting and “stemming” to reduce the amount of energy that would impact fish. In addition, fish avoidance techniques will be utilized to drive fish away from the proposed blasting area to reduce the detrimental impact to the fish and benthic community. Monitoring impacts to fish from the blasting will also be conducted to verify that impacts are minimal.

The pre- and post-blast monitoring for fish including shortnose sturgeon shall be conducted under the supervision of a principal biologist that has at least a Master of Science degree in fisheries biology or similar fields and must have obtained in their name the appropriate ESA permits to work with shortnose sturgeon.

F. EFFECTS ON EFH AND DESIGNATED SPECIES

The following impacts are expected to occur during construction of the deepening project:

A loss of benthic resources will occur in channel dredging areas and at the Kelly Island and Broadkill Beach beneficial use sites. This will have an immediate, albeit temporary, minimal effect on the feeding success of species dependent on benthic invertebrates. Recolonization of the benthic community will occur through: 1) benthic infauna that were not entrained during dredging operations, 2) migration of juvenile and adult infauna from contiguous areas, and 3) larval infauna that settle on the new substrate.

A potential for physical injury to designated species as a result of entrainment by a working dredge. This is more likely for newborn sharks and smaller juveniles of designated species, as older juveniles and adults would be expected to move out of the way.

A potential for physical injury to designated species as a result of rock blasting in the vicinity of Marcus Hook, PA. Blasting is scheduled to take place during the months of December and January. No designated species are expected to occur in this part of the river at this time of year.

A temporary increase in turbidity at the dredging and placement sites. Typically, turbidity associated with dredging will reach background levels within an hour or less after dredging stops, dependent upon the composition of the material being dredged.

The following measures have been incorporated into the construction plan to minimize impacts:

Best management practices will be used to minimize potential effects.

To protect the anadromous fish (striped bass, American shad, river herring) spawning run in the Delaware River the Delaware Basin Fish and Wildlife Cooperative recommends that dredging be restricted between the Delaware Memorial Bridge and the Betsy Ross Bridge from March 15 to June 30 for hopper dredging and March 15 and July 31 for hydraulic dredging. These restrictions would apply to Reaches AA, A, and B of the project area. These restrictive periods will be met throughout the construction period. In addition, for protection of overwintering blue crab, no dredging will occur during the months of December through March in the lower Delaware Bay.

Construction at the Broadkill Beach site will be managed to minimize discharge of sediment to shallow water areas between 1 May and 15 September for protection of sandbar shark pups and juveniles. This will also benefit early life stages of winter flounder.

Implementation of a monitoring plan to protect fish in the vicinity of the rock blasting zone.

G. CONCLUSION

Based on the foregoing, it is concluded that there would be no more than minimal impact to designated species or designated species' EFH as a result of the planned construction of the Delaware River Main Stem and Channel Deepening Project.

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